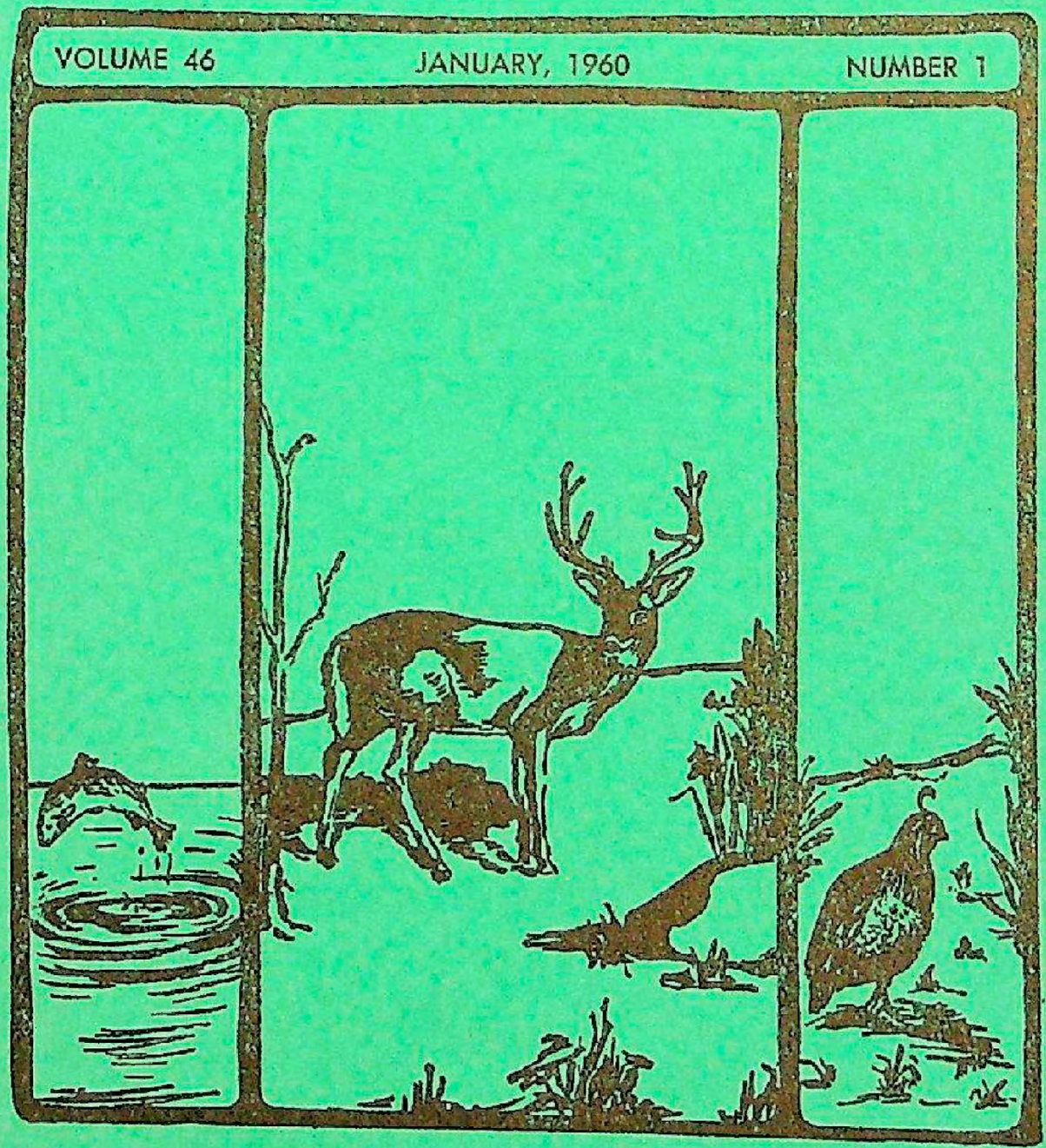
CALIFORNIA FISH AND GAME

"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

VOLUME 46 JANUARY, 1960 NUMBER 1



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CALIFORNIA FISH AND GAME

VOLUME 46 JANUARY, 1960 NUMBER 1

Published Quarterly by the
CALIFORNIA DEPARTMENT OF FISH AND GAME
SACRAMENTO

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DEPARTMENT OF FISH AND GAME

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A SURVEY OF FISH TRANSPORTATION METHODS AND EQUIPMENT[1,2]

KENNETH S. NORRIS, FRANK BROCATO and FRANK CALANDRINO, Marineland of the Pacific, and WILLIAM N. McFARLAND, Institute of Marine Science, The University of Texas, Port Aransas, Texas

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[1] Submitted for publication September, 1959.
[2] Contribution Number 5, Marineland of the Pacific Biological Laboratory.

INTRODUCTION

The transport of live fishes is becoming an increasingly important problem. Fish and Game agencies, aquariums, commercial bait dealers, commercial fishermen and people catering to the home aquarium trade all must transport living fish. In general, all wish to carry as many fish as possible in as little water as possible with a minimum of mortality. These attempts inevitably bring all the factors limiting to fish during transport into sharp relief. Much further improvement in transport efficiency seems possible.

As a foundation for the development of new equipment and methods at Marineland of the Pacific, we have attempted to gather all available information on present fish transportation practices. Ninety-six state, federal government and private agencies, and individuals have been polled for transport data. The published literature has been reviewed. From these sources and from our own experiences we have compiled this review. The discussion has been limited primarily to principles and methods. Construction methods are not reviewed in detail, except where they have a direct bearing upon the welfare of the fish being transported. Where noteworthy information was derived from the poll, appropriate source notations are cited in parentheses. Literature references are given in normal fashion.

HISTORY OF FISH TRANSPORTATION

From far back in Chinese history there are records of the culture and transport of fish spawn. The Romans too, cultured and transported fish (Norris, 1874, pp. 16-18); however, little improvement of methods occurred until very recent years. Within the last 90 years, transport techniques have changed from the use of dippers and metal cans to modern transport tankers, with their complicated circulating systems.

The first major shipment of live fishes reached California waters in 1871. It consisted of about 12,000 American shad fry *(Alosa sapidissima)* brought from the Hudson River, New York, to Tehama, California, in barrels. In 1879 Dr. Livingston Stone collected 133 striped bass *(Roccus saxatilis)* at Red Bank, New Jersey and brought them across country in a freight car. The fish cans were cooled with ice. Dr. Stone hired fellow passengers to help with the hand aeration of the cans. By this incredibly tedious means all but 25 fish arrived in California alive and were planted at Carquinez Straits. Another shipment under the care of J. G. Woodbury left on July 17, 1882, from the east coast and arrived at the planting site on July 25 (Shebley, 1927). A new device that was considered a great improvement, but which also involved laborious manual operation, was used during this trip. A cylinder, the bottom perforated with fine holes, was pushed into the water, allowed to fill, and removed, resulting in a fine shower of water.

One of the first attempts to transport marine fishes was reported by Thomas Moore in 1887. He discussed the transport of a flatfish, *Solea* sp., from England to the east coast of North America. The fish were landed successfully at Cold Spring Harbor Hatchery on Long Island, but failed to establish themselves.

Many methods of aeration have been devised. Raveret-wattel (1880) described an ingenious device for oxygenation of the water in casks that were pulled on a horse-drawn cart. A blacksmith's bellows was geared to the axle of the cart by an eccentric so that movement caused it to pump a stream of air into the casks. A clever transportation tank, decked over to prevent sloshing, was described by Anon. (1883). Salt water was circulated from an overflow, through a filter, and then pumped into an overhead storage tank where it was aerated and returned to the main tank by gravity. Trips of 72 hours duration, from Trieste to Berlin, were made using this gear, with apparent success. Also mentioned was the use of concentrated sea water (reduced to one-sixth its normal volume) to refresh the tank and to make up for lost water en route.

Holder (1908) described a sponge-lined tank capped with a false-bottomed lid perforated with tiny holes. Any movement of the container caused the water to flow into the lid and cascade out again, thus aerating the water. The sponge lining provided springy walls which would not injure the fish. An apparatus was described by Lorenz (1903) in which a small oxygen cylinder was submerged to the bottom of a transport tank and the gas forced through an air stone. Seale (1910) used one of the first motor driven pumps for aeration during his month-long transport of black bass (*Micropterus*) from California to Bagio in the Philippine Islands.

Fisher (1915) discussed the transportation and planting of trout fry in California waters and described his techniques and equipment as follows: "Two things must be carefully watched—the temperature and aeration of the water. A lowering of temperature or lack of air quickly affects trout fry. The necessary equipment must include a thermometer and a dipper. The ordinary thermometer to be purchased at any notion store is as good for this purpose as a higher priced one, and an ordinary handled dipper having a cover of wire screen soldered over the top of the bowl is all that is required."

In a study of techniques of raising various marine animals, Mead (1908) outlined the factors he considered essential for the transport of living fishes. He said, "The principle is, briefly, to provide at the start native 'unmodified' water; to maintain proper temperature and density, and in some cases current; to secure continuous 'respiration' of the water, including egress of waste gasses of the metabolism of contained fishes and often bacteria as well as the access of oxygen, and to avoid contact with injurious metallic substances." This statement represents a reasonably inclusive summary of present-day thinking on transport problems, although other factors such as removal of slime, deciduated scales and egested material are now recognized to be important.

From such beginnings as these came our modern and quite diverse equipment and methods. We have summarized information from our poll in the pages that follow and have added pertinent material from the published literature.

TANK CONSTRUCTION AND MATERIALS

Tank Design

In the United States the majority of transportation units are constructed of welded steel. These tanks have the advantages of strength, ease of construction and relatively low cost. They are heavy and, as a result, reduce payloads. One agency has reported good success with aluminum tanks (U. S. F. & W. S., Minneapolis). These are easily portable up to about 200 gallons capacity.

Wooden tanks are still in widespread use. Most are built of heavy bolted planking. They are very heavy but have the advantage of supplying far better thermal insulation than either steel or aluminum.

Four agencies report converting from metal to fiberglassed plywood or fiberglass tanks (Idaho, F. & G.; New York Aquarium; N. Y. Conserv. Dept.; Montana F. & G.). The New York Aquarium uses fiberglassed plywood tanks lined with polyethylene resin. At Marineland of the Pacific we have used a fiberglassed plywood tank for four years, with excellent results. This type of construction has several advantages; it is lightweight, inexpensive, has fairly good insulation qualities and is very strong. One major advantage is that repairs or changes can be made quickly by any carpenter. In addition, metal corrosion and the leaching of tannin such as often occurs from ordinary wooden tanks cannot take place.

Insulation

The importance of maintaining low water temperatures while transporting large weights of trout per unit volume is well known. Many of the newer truck units are insulated in some way, to reduce heat flux during icing or refrigeration. The material that has been most used is rock wool. Styrofoam (Montana F. & G.), a Dow Chemical Company product, and cork (Georgia G. & F. Comm.) are also in use. These materials are employed as jackets covering the transport tank, and in some cases the circulation lines, or as fillers between rigid double walls.

Of the materials in present use Styrofoam is the best insulator. Its thermal conductivity (K factor = B.T.U./in. thickness/sq. ft./hr./° F.) is 0.23 to 0.27 at a mean temperature of 40 degrees F. (Styrofoam Product Information Leaflet No. 875, 1957). Styrofoam can be cut into any desired shape and may be applied as thin planks or slabs to the sides of tanks. Glass cloth and resin may be overlayed on Styrofoam if a sheet of metal foil is interposed. The resin will dissolve the unprotected insulation. Both the Wisconsin and Montana State Fish and Game Departments report that insulation virtually eliminates the necessity of icing on short hauls while long trips can be made with only minor temperature fluctuations. Insulation is advantageous in transporting tropical fish over long distances where temperature decline can be a serious problem.

Tank Shapes

The great majority of transport trucks used in fresh water fisheries work are rectangular. Most tanks above 500 gallons capacity are baffled to reduce sloshing (Copeland, 1947). Spray aeration systems are commonly used in this type of tank and the water level is usually main-

tained a few inches below the top to allow the water to fall through air for a short distance. Sloshing is more acute in spray aerated tanks than in Venturi or diffuser aerated tanks since the latter types can be filled to the top (Horton, 1956). In bait tanks used on marine bait boats and tuna clippers and in some spray aerated truck tanks the sloshing problem has been eliminated by restriction of the tank opening to an elevated combing. The water level is raised into this combing so that the majority of the water surface is directly covered by a rigid tank top. Baffles are nearly always absent in these tanks (Marineland of the Pacific, New York Aquarium). When spray aeration is employed, the water is sprayed directly into the combing. Distribution of aerated water to all parts of such a tank is probably inefficient.

A common experience has been that the larger the tank the less weight-per-unit-volume of fish that can be carried. This is probably due to increasingly poor mixing and replacement of tank water as tank size increases. One factor is the thickness of the water mass that must be aerated (Macklin, 1959). If volume is increased primarily by increases in surface area and not depth, and each new increment of area is supplied with aeration equivalent to the level obtained in smaller tanks, no loss in load capacity should result from increased water volume.

Cans and barrels are in regular use for short term hauls of fry, and for inaccessible locations by pack and burro. The cans are generally made of metal and are rounded and broad-bottomed. Most are fitted with lids with perforated false bottoms. Movements of water in the restricted neck of the can cause water to pour into the lid and cascade out again.

Capacities

The sizes of truck transport tanks are dictated primarily by the means available for hauling and the distances involved. For short local hauls, fish are either carried in cans (Prather, et al., 1954) or barrels, or in tanks that can be placed on small trucks. Sometimes banks of several small tanks are used (Indiana Dept. Conserv.). Such moveable tanks usually do not have capacities greater than 300 gallons. Tanks for longer hauls of large quantities of fish average about 1,000 gallons capacity. A few units carry as much as 2,000 gallons (Idaho F. & G.).

Miscellaneous Construction Features

Few reports of tank lighting or viewing ports were received (Calif. Dept. F. & G.). It was the opinion of some correspondents that the presence of light is not essential for the transporation of fresh water game fish (California Dept. F. & G.). Bait tanks that haul schooling fish have lights suspended over the middle of the tank (Tuna Boat Owners Assn.). This promotes the formation of a 'mill' of fish circling slowly under the light. Without lighting, such fish tend to batter themselves on the walls and corners, and soon die. Bait species of the genera *Engraulis*, *Anchoa*, *Cetengraulis* and *Harengula* require lighting.

Watertight ports, though seldom mentioned, would seem to have considerable utility for most types of fish transport (Calif. Dept. F. & G.). The condition of water and fish can be checked much more effectively by viewing laterally through the water than from above.

In trout transport, uncovered ports are reported to cause fish to crowd together at the glass (Calif. Dept. F. & G.). An opaque cover left in place except during viewing should eliminate this problem.

The interiors of most trout transport tanks are rectangular, but tanks used in the transport of alewives (*Pomolobus pseudoharengus*) are rounded and have a circular flow of water induced by jets (Sykes, 1951). Many salt water bait tanks have rounded corners. Where many fish species are carried, as in aquarium transport, rounded corners are advantageous because a few species at least will tend to become trapped in rectangular corners.

Occasionally, fishes that tend to concentrate at the bottom of transport tanks have been dispersed throughout the entire tank volume by means of screen racks or horizontal shelves (Lorenz, 1903, ling cod (*Ophiodon elongatus*) holding tanks, Wis. Cons. Dept.). Such an arrangement tends to minimize the localized dissolved oxygen deficiency but increases the difficulties of loading and removal.

Circulation Equipment

Pumping and Circulation Rate

The major problem in circulation is to supply freshly aerated water as rapidly as possible to all parts of a transport tank. Success is dependent upon tank shape, location and efficiency of aeration devices, circulation pattern and water turn-over rate in relation to loads to be carried. Simple tests, using dye in the incoming water will often help to determine efficiency of circulation in a given unit, as its spread can be watched and timed.

By far the most commonly used method of water circulation for spray-aerated tanks employs a self-priming centrifugal pump powered by a small gasoline engine. Many such units employ standby engines in case of failure.

A California Department of Fish and Game 1,500-gallon unit uses electrical power derived from a motor generator. This design has the advantage that various auxiliaries such as compressors and lighting circuits can be run from the same power source (Figure 1). Standby electrical units are in limited use. These may be plugged in to a standard 115-volt AC electrical circuit when the transport truck is parked.

The use of propane powered engines was reported by one state (Montana F. & G.). Power takeoffs from the transport truck engine have also been successfully used. An ingenious hydraulic power-takeoff system has been described by Stubblefield, Lefevre and Smart (1949).

Little published information is available on circulation rates for the various transport units. However, circulation rate has been found to be one of the most important features of design in salt water bait tanks. A close correlation is reported to exist between the weight of bait fish that can be hauled and the number of turnovers of water per hour (Carlson, 1955). Bait haulers sometimes describe turnover rate with the phrase, *"a six-minute tank"* or *"a 10-minute tank."* A six-minute tank is simply one in which the entire water volume is recirculated or replaced every six minutes. Generally fresh sea water is supplied to bait tanks at rates varying from a turnover every six minutes to about

FIGURE 1. The California Department of Fish and Game 1,500-gallon tanker. This unit employs two generators, two refrigeration systems and Venturi aeration.

one in 12 minutes. A six-minute turnover was reported for the 1,000-gallon unit used by the State of Nevada. Interestingly, the weight of fish transported per unit volume for this tank (1.4 pounds/gallon) is one of the highest on record (Table 1). The most efficient tank in use today employs the highest turnover rate. An experimental 150-gallon spray-Venturi aerated tank carried up to four pounds per gallon at a circulation rate of once every 1.5 minutes (Macklin, 1959). The success of this tank was shown to be due primarily to its high turnover rate.

Eight- to 12-minute tank recirculation rates are reported for live wells on tuna clippers (Carlson, 1955).

Our data are very incomplete but indicate that most transport units employ pumps and engines which result in turnover rates well below this level. More usual turnover rates appear to be between 15 and 20 minutes. Controlled tests of the effects of turnover rate are needed and should provide valuable information for increasing the efficiency of transport gear.

Aeration Equipment

Gas exchange between transport water and the atmosphere is universally recognized as a primary problem in fish transport. Too often, both in thought and in practice, attack on this problem is limited to keeping oxygen tensions at high levels. The problem of aeration is much more complex than mere maintenance of oxygen levels. It involves equilibration of carbon dioxide, reduction of dissolved ammonia, and the maintenance of proper pH levels, in addition to oxygenation (Fish and Hanavan, 1948; Phillips and Brockway, 1954; McFarland and

FIGURE 2. Spray aeration in the State of Washington, Department of Fisheries 1,000-gallon tanker. The water level in the tank with a full load is normally 6 to 10 inches below the jet nozzles.

Norris, 1958; McFarland, 1958; and Fry and Norris, ms.). Little is known concerning the characteristics of aerators now used for controlling these additional factors. It seems probable that since these factors generally vary in a rough positive correlation with oxygen levels (with the possible exception of ammonia), they have usually been maintained somewhat above lethal levels by application of the "oxygenation principle." Critical study of aeration systems on a broad basis, with testing of fluctuations of each major factor, is one of the major needs of transport experimentation.

Aeration is accomplished in five major ways in present-day transport tankers; spray, baffles and screens, Venturi, compressed gas liberation and agitation. Also in sealed systems, as are universally used in the air transport of tropical fish, pure oxygen is supplied to the airspace over the water. Each of these will be considered in turn.

Spray Aeration

This method involves forcing tank water through jets or perforated pipes which spray it through an air-space back into the transport tank (Figure 2). The water is usually pumped from the lower parts of the tank to promote water turnover. Nevertheless, inadequate turnover of all parts of the tank water is a common problem. Intimate contact between air and water can be achieved by spray aeration and hence it is

potentially a very efficient means of gas exchange (Copeland, 1947). Scales, slime and other debris tend to clog jets or spray nozzles unless the orifices are large or a strainer or filter is interposed. Contact between air and water may also be increased by use of air scoops or blowers which force air onto the spray streams (Olson, 1940).

Baffles and Screens

Normal movements of tank water during transport have been used to supply supplementary aeration. Surface water is agitated and broken up as tank movements sweep the water into screens and perforated lids, or against wooden baffle bars (Ohio Dept. Nat. Res.). As movement sweeps the tank water away from the baffle, trapped water cascades back into the tank, thus providing aeration of a limited sort.

Screens interposed between spray jets and the water surface may be used to produce finely divided sprays (Wall, 1948).

Venturi Aeration

A volume of air can be drawn into a moving stream of water through an orifice in relation to the speed of the moving water and the shape of the chamber through which the water passes (Figure 3). This principle is used both for drawing air into transport tanks and in water-operated vacuum pumps. Many large transport tanks are aerated by means of Venturi systems (Copeland, 1947). Because the incurrent aerated flow can be directed in such a way as to reach all parts of the tank, reasonably uniform distribution of aerated water can be obtained.

Venturi and spray aeration both cause violent mixing and may result in excessive foaming (Stubblefield, Lefevre and Smart, 1949). Also, some narcotics tend to increase the amount of foaming (Skinner, 1955). It is probable that foaming reduces the efficiency of aeration by reducing gas exchange. Organic anti-foaming compounds have been used in fish transport tanks (Skinner, 1955; Macklin, 1959). While Venturi aeration is effective in raising oxygen tensions (Horton, 1956), little is known of its efficiency in control of other aeration parameters, such as carbon dioxide.

Venturi aerated water is apt to be filled with fine bubbles upon introduction into the tank. Such bubbles are thought by bait fishermen to be lethal to certain filter-feeding marine fishes (*Engraulis* etc.).

Compressed Gas Liberators

The most common method of transport tank aeration is the liberation of compressed gasses through diffusers placed on or near the tank bottom. High pressure medical oxygen, held in cylinders and released through a pressure regulating valve, is the most commonly used gas, while gasoline motor driven air-compressors have a more limited use. Compressed gas liberators are most widely used on small portable transport tanks but often are standard equipment on large permanent truck units as standbys. Many kinds of gas diffusers are in use. In the most popular type, the gas is forced through a block of hard porous material (Copeland, 1947). Commonly used materials are carborundum, carbon, porcelain (Greene, 1956), and brick. Another type utilizes a perforated tube into which gas in introduced under pressure (New York Cons. Dept. U. S. F. & W. S., Minneapolis). Such tubes are generally ar-

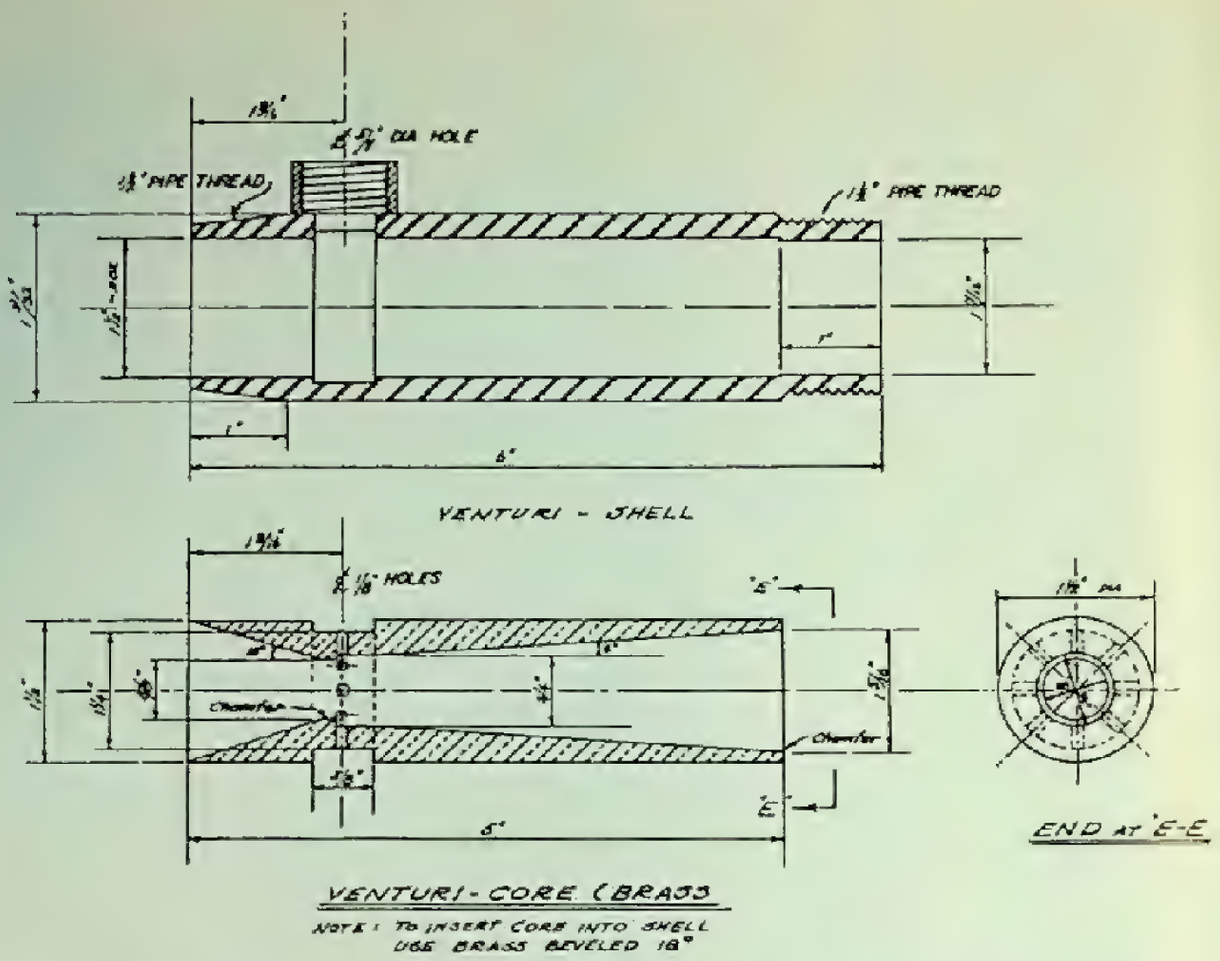

FIGURE 3. Plan of Venturi core and shell used in the California Department of Fish and Game 500-gallon tanker.

ranged in loops or rings around the tank floor. In this way gas bubbles can be made to reach nearly every part of the tank water. The tubes are most often made of copper or brass but rubber and plastic laboratory tubing are also employed (New York Cons. Dept.).

Gas diffusers have the great advantage that there is little chance of mechanical failure since the gear is simple. The uniform mixture of gas and tank water that can be obtained is highly desirable. Since pure oxygen is usually employed, oxygen tensions can be quickly raised by gas diffusers. The efficiency of this sort of aerator for control of waste gasses and pH is not known though it has been demonstrated that CO_2 can be equilibrated by them (Fry and Norris, ms.). A unique modification of a gas diffuser has been described by Brock and Takata (1955). This aerator utilizes the *air lift* principle (Figure 4). Gas forced through a carborundum block causes a column of air to rise inside a wide metal tube. This column of air draws water into the tube where it rises to the surface and spills back into the tank. This effectively aerates the water as it is raised. Another unique aeration method has been used by the Tennessee Game and Fish Commission. Aeration is supplied to small portable transport cans by use of a vacuum tube from the intake manifold of the transport truck. By partial evacuation of the gas over each tank air is drawn into the water through a tube and airstone leading from the atmosphere into the tank water.

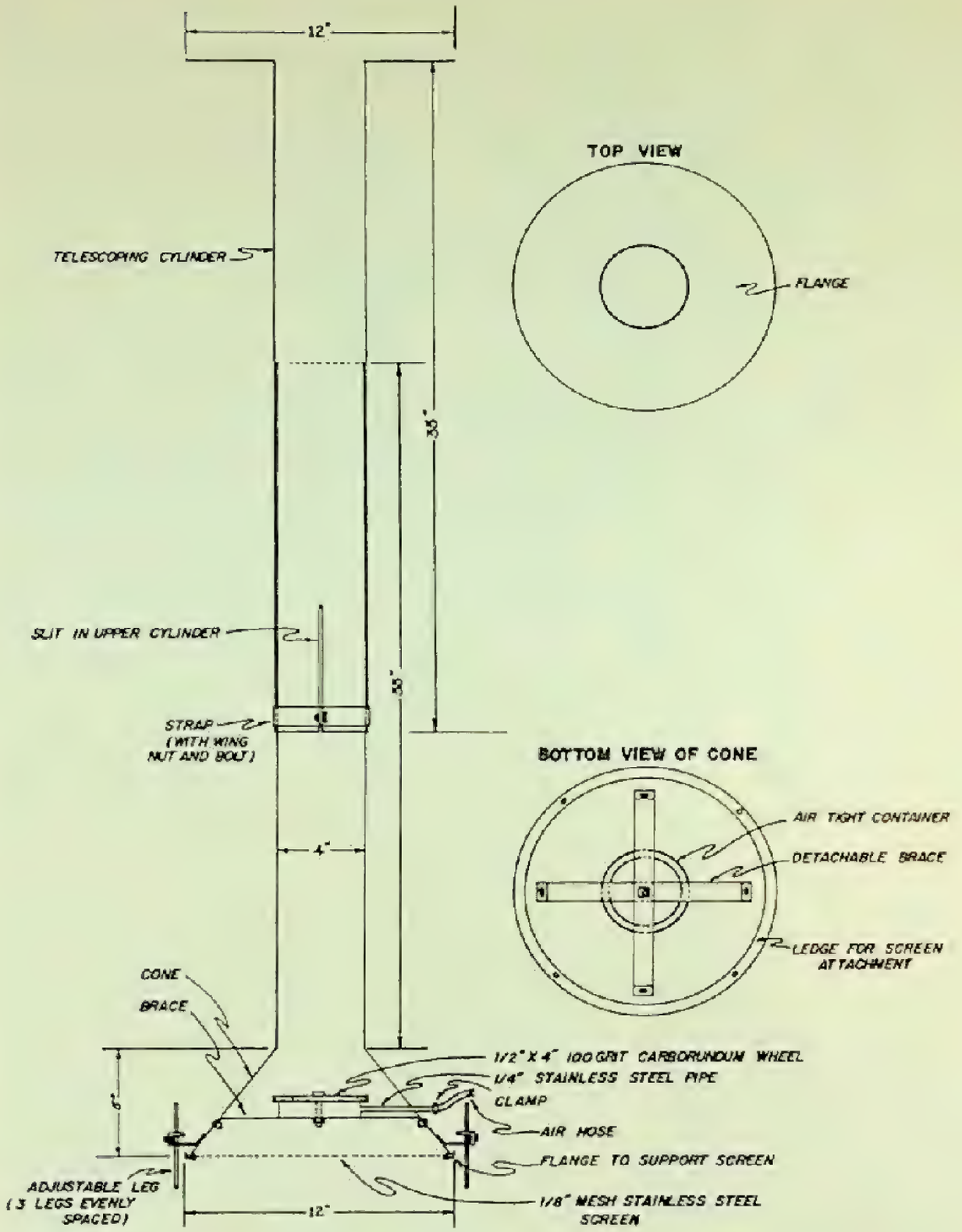

FIGURE 4. Air-lift aerator (from Brock and Takata, 1955). Compressed gas forced through the carborundum stone at the bottom of the pipe lifts a mass of water with it as it rises, spilling it over the top, back into the tank, or first through a filter.

Agitators

Air can be dispersed throughout a transport tank by simple mechanical stirrers that produce a vortex at the water surface. The stirring blades are usually long enough so that the top end extends close to the surface while the lower end is well below water level (Figure 5). Aeration by use of agitators shows great promise and is in increasingly

widespread use (Tenn. G. & F. Comm., Alabama Polytechnic Inst., Texas F. G. & O. Comm., Minnesota Dept. of Cons.). Some advantages of agitator aeration are that gas exchange is performed continuously throughout the entire volume of transport water, a current is set up which serves to scour the tank corners of stagnant water, equipment is simple and inexpensive to operate. Air is not mixed with transport water as intimately as with spray aeration or Venturi aeration, and as a result the foaming problem is probably less acute. Judging from the excellent results that have been reported for agitator aerated tanks, gas exchange is probably performed quite efficiently. However, experimental data on the control of the several water quality parameters by agitation are badly needed.

A unique modification of the agitation principle has been presented by Stubblefield, Lefevre and Smart (1949). This consists of a hydraulically operated agitator with a hollow-bladed propeller. The incoming air is swept into the water through openings along the trailing edge of the blades. Good results are reported with this gear but once again, quantitative data defining its effects upon the various factors in water quality are lacking.

A defect of the agitator method is that the propellors must be screened to prevent fishes from coming in contact with the blades, thus reducing both stirring and aeration efficiency to some extent, as well as the effective tank volume. These factors apparently are not serious. Since the mixture of water and gases is somewhat less intimate in agitator than in spray or Venturi aeration it becomes even more imperative that the total gas-exchange efficiency of the method be determined.

In areas where very low winter temperatures are common, agitator units are reported to freeze up (Minnesota Dept. Conservation). It seems certain that this problem can be avoided.

Filtration Equipment

Perhaps the most neglected method of maintaining the quality of transport water is filtration. Fish slime and regurgitated food often become mixed into tank water by the aeration devices and cause foaming (Skinner, 1955), bacterial proliferation (Vaas, 1952) and consequent reductions in water quality. The methods of filtration in use on modern transport equipment, as revealed by our survey, are all primitive. In spite of low efficiencies of the gear, agencies that reported the use of filtration also reported that it was considered a valuable means of controlling water quality (Copeland, 1947). The methods used serve to remove large particulate matter such as large pieces of regurgitated food, and deciduated scales, but have very low filtering efficiencies for colloidal materials, slime and bacteria. In general, where filtration is used, circulated water is run through cheesecloth bags, over intermeshing pig bristles or through fine-mesh metal strainers, or through combinations of these components. Bruce Kimsey of the California Department of Fish and Game (pers. comm.) reports good success in the use of a homemade gravity filter during transport of threadfin shad (*Dorosoma* sp.) from Tennessee to California. The California Department of Fish and Game reports the installation of a filter on one of their smaller tankers. No indications of the effectiveness of this gear have been received.

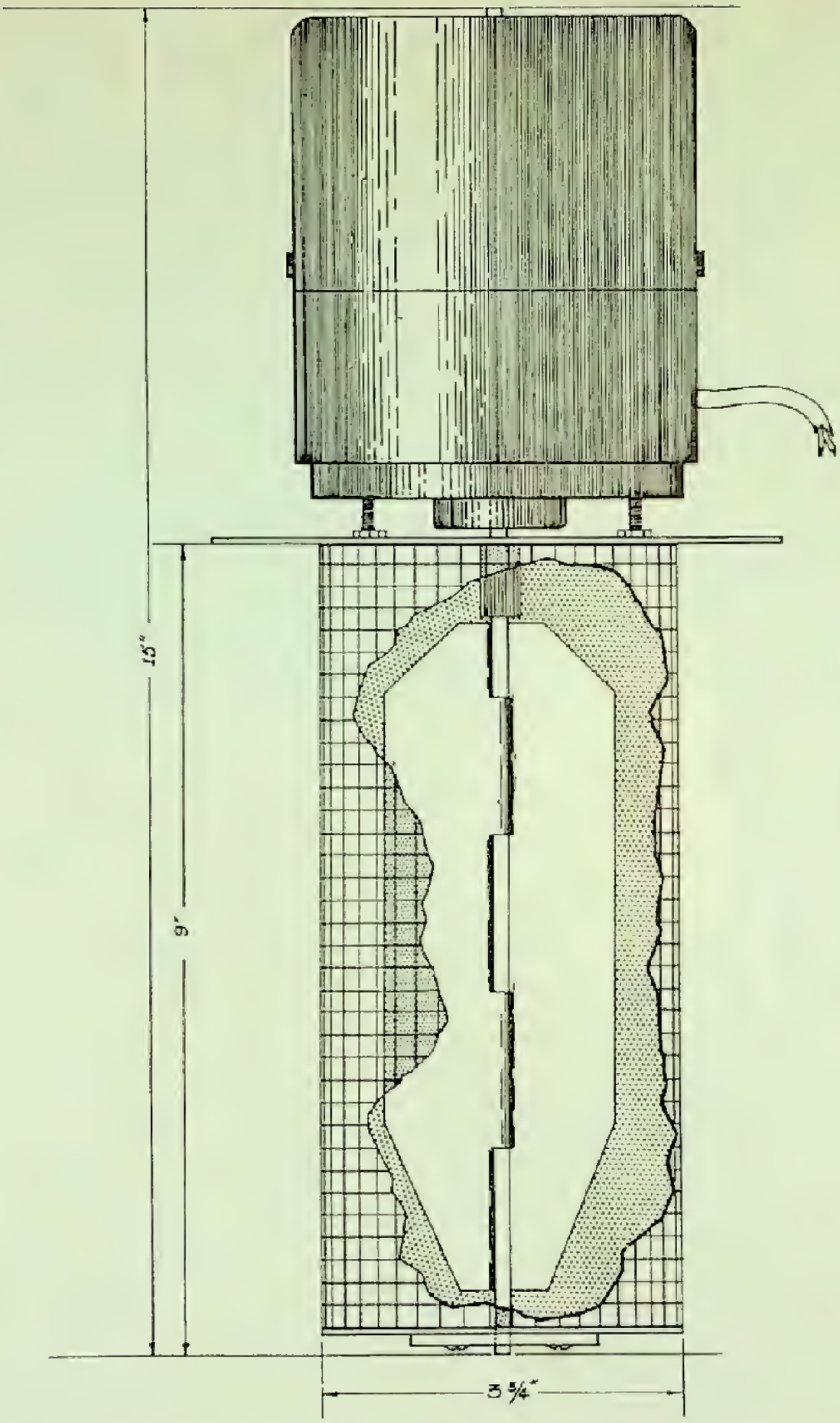

FIGURE 5. Agitation aerator, showing motor, elongate stirring blade, and protecting screen.

At the suggestion of Dr. Boyd Walker of the Department of Zoology, University of California, Los Angeles, a pressure filter was installed on the Marineland of the Pacific transport truck. This unit is a standard swimming pool filter consisting of a cylindrical tank with a removable top and gasket, an interior mesh basket, and a synthetic cloth filter bag. Circulation water can be shunted through this filter at a rate of 50 gallons per minute as desired, by a system of by-pass valves. Before operation a two-pound coffee can full of diatomaceous earth filter medium is dumped into the bag and the top of the pressure filter bolted in place. The incurrent water pressure causes the diatomaceous earth to be spread evenly over the inside of the bag in a thin layer, through which the water is then filtered.

In a test, the water in the 1,200-gallon transport tank was dirtied to opacity with mud. Within 45 minutes it had become so clear that only a slight brownish cast to the water remained. In actual operation, during trips of as long as 1,000 miles, the filter functioned well and was thought to be essential to success. However, the slime from transported fishes tended to clog the filter much more rapidly than the suspended silt of the initial test. The filter bag was cleaned and new diatomaceous earth added on the average of once every three hours. A pressure guage attached to the filter enabled us to tell when the filter medium had become clogged and needed replacement.

There are many features of the filtration operation used on the Marineland truck that need refinement. The ratios of filter capacity to circulation rate and tank volume are obviously too small. A filter that requires backwashing and replacement of the filter medium only between trips should be simple to design.

It seems obvious that if a filter such as that used by Marineland can be clogged every three hours with relatively slight loads (1 pound/4 gallons) the need for filtration is great. The value of the diatomaceous earth filter is clearly evident because foaming was virtually eliminated, and water clarity remained good on hauls involving as much as 40 hours of continuous operation. However, again experimental data are needed to determine the effects of such filtration on water quality parameters.

Fish Weighing Gear

One of the most important phases of any transport operation is the transfer and weighing of the fish as they are loaded into the tanker. Without a reasonably precise figure for *weight of fish per unit volume* no meaningful data can be gathered of the effects of various water quality variables upon mortality. Since a buoyant fish is presumably virtually in isostatic balance with the water of its medium, its weight can be calculated from volume displacement data. Therefore, it is possible to facilitate rapid loading by use of displacement measurement. Thus the tanker is filled to a known level and fish are added until the water reaches a specific level indicative of the specified load. Water levels are measured either by means of a sight glass mounted outside the tank, a calibration scale inside the tank, or by topping the tank to the level of an overflow controlled by a valve and then measuring the volume of the excess water. The last method is the most accurate, particularly on large tankers. However, sight glasses have proven ade-

FIGURE 6. Escaweigher. An automatic loading device employing a compartmented rubber conveyor belt (Leitritz and Macklin, 1956).

quate during operation and are much easier to use than the topping-off valve.

Often, it is not known if a fish is in isostatic balance with its medium and displacement weighing cannot be used with accuracy to determine weight unless the density of the species concerned is predetermined. Therefore, fish are introduced dry in known weights, or in estimated weights or numbers in a given volume of water. An ingenious loading device called the "escaweigher" has been described by Leitritz and Macklin (1956) (Figure 6). It utilizes a rubber conveyor belt which loads directly into the tanker. The fish arrive at the tank out of water and a rather accurate weight can be obtained by simple displacement for isostatically balanced fish.

Many species of fish are extremely susceptible to injury from handling. Therefore, it is highly desirable to transfer such forms without removing them from water. For example, commercial bait haulers catching and holding the northern anchovy, *Engraulis mordax*, reported appreciable losses after transfer of the fish from bait boats to holding wells. Fine-mesh dip nets were usually used for transfer. Recently, a canvas bucket that can scoop up a quantity of fish in water has been employed. Since the fish never leave the water during transfer, they are seldom injured. Losses in the holding well are reported to be low since use of the canvas bucket was begun.

Temperature Control

Temperature control has been achieved almost universally by means of ice and insulation. However, three agencies report having installed motor-driven refrigeration units and heat exchangers on their larger units (Idaho F. & G., Calif. Dept. F. & G., Montana F. & G.). The California Department of Fish and Game reports the use of Freon-12 refrigeration units on their 1,590-gallon tankers. The refrigeration capacity is four tons at a five-degree temperature differential. Two agencies (see Stubblefield, Lefevre and Smart, 1949, and Olson, 1940) mention the use of evaporative cooling. Considerable success was achieved in keeping water temperatures moderate during hauls on exceedingly hot days by evaporative cooling (Olson, op. cit.).

A refrigeration unit of five tons capacity at a three-degree temperature differential was installed on the Marineland of the Pacific transportation truck but proved to be inadequate to control the temperature of the 1,200-gallon tank. Since that time ice has been used. The small dilution produced in salt water transport (less than 10 percent) has had no deleterious effect and is well within the tolerance of most stenohaline forms. Refrigeration equipment has the disadvantage that it is bulky, heavy, very expensive and subject to mechanical failure. Its limited use on transportation units can be best attributed to these factors.

Many units using gasoline engines directly connected to circulating pumps add materially to their temperature control problems by conduction of heat from the engine through the pump shaft to the pump impeller blades and then into the tank water. Pumps that are connected by belts to the engine eliminate this problem. The very efficient transport tank described by Macklin (1959) uses direct drive gasoline-engine-powered pumps. A rapid temperature rise is reported for this unit. Almost certainly this problem could be greatly alleviated by use of belt-driven pumps.

Since Mexican warm water forms are often transported by Marineland, as a general rule control of declining temperature is of more importance than control of rising temperature. Therefore a stainless-steel heat exchanger using bypassed exhaust gases from the truck engine is used to heat the tank water. By manually operated valves water can be shunted through the exchanger or bypassed directly into the tank aerator. The tank can be warmed quickly with this device.

Various warm water game fish may sometimes require warming of water during transport. Prather, et al. (1954), report that 60 to 70 degrees F. is the optimum temperature range for the transport of two species of bait minnows (*Pimephales promelas* and *Notemigonus crysoleucas*).

The basic information that is needed before a policy can be set regarding temperature control during transport is the relation of temperature to metabolic rate and death for each species (Fry, 1947) (Figure 7). Where one or two major species are to be transported such information should be obtained experimentally. Where a variety of species are to be hauled, as in aquarium work, an estimate of the thermal regime from which the fish come must necessarily serve as a guide.

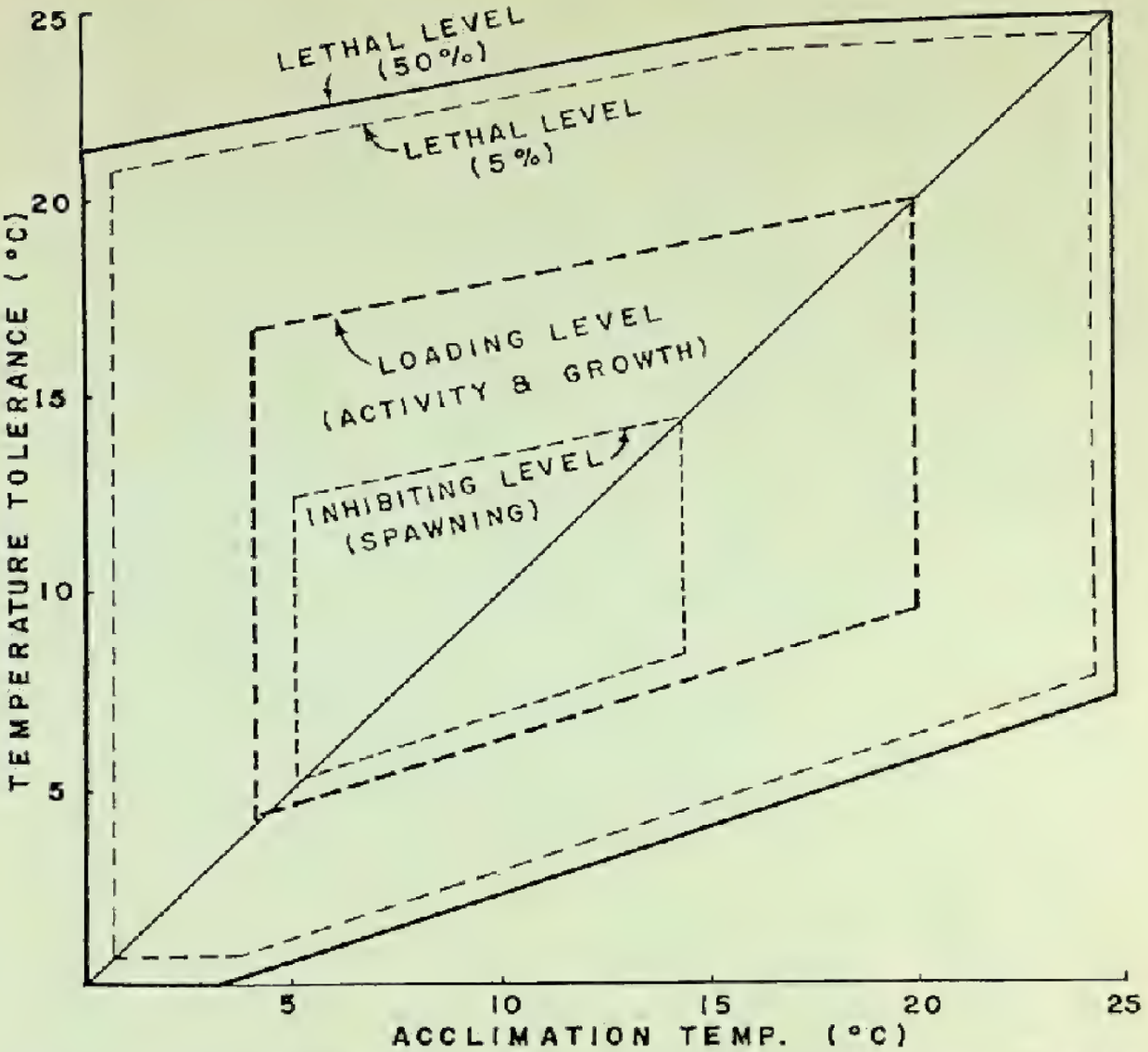

FIGURE 7. Zones of temperate tolerance for young Sockeye Salmon (redrawn from Brett, 1958). Loading and inhibiting levels are yet to be determined, and are merely suggested here. The limits of the loading level are probably of particular importance in the transportation of fish, and determination should be attempted for the major game species.

Waste Products and Chemical Control of Water Quality

Excretory products, slime, deciduated scales, decomposition products from dead fish, and regurgitated food may reduce water quality to critical levels on long hauls. Some measure of control of reductions in water quality brought on by these factors may be achieved by chemical means. Buffering, chemical absorption of nitrogenous wastes and the use of bactericidal and fungicidal agents are methods that have received some attention. In practice none of these methods seems to be in regular use, though all hold promise. Each will be discussed briefly.

Carbon dioxide from fish and bacterial respiration tend to acidify transport water. Increased carbon dioxide and increased acidity reduce the affinity of fish bloods for oxygen (Bohr effect). Mortality can ensue as a result of high carbon dioxide tensions or increased acidity, even in the presence of seemingly adequate levels of oxygen. Buffering stabilizes acidity and thus allows fish to utilize oxygen more effectively in aerated tank water. Buffering of fresh water can be achieved with inorganic compounds such as phosphates (Vaas, 1952; and Srinivasan, Chacko

and Valsan, 1955), but some workers report either doubtful utility (Nemoto, 1957), or completely negative findings (Saha, Sen and Mazumdar, 1956). Inorganic buffering compounds are ineffective in sea water (McFarland and Norris, 1958), since they cause either precipitation of calcium salts or buffer in undesirable ranges of acidity. These workers report that an organic buffer (Tris-hydroxymethyl-aminomethane) is very effective in both salt and fresh water and have used it on 29 different species of fish without ill effects. The compound is highly soluble, does not cause precipitation of calcium in sea water, is apparently stable for long periods, can be applied easily in the field with little experience and will increase the acid-absorbing capacity of sea water by as much as 50 times at 20 grams per gallon. Dosages of 5 to 10 grams per gallon are probably sufficient for most normal transport operations.

Nitrogenous wastes, particularly ammonia, may be highly toxic (Brockway, 1950; Phillips and Brockway, 1954; and Doudoroff, 1957). Certain resins are reported to have the capacity of absorbing these wastes (Nemoto, 1957; Saha, Sen and Mazumdar, 1956), but most also absorb oxygen from solution. Ammonia is apparently difficult to remove from tank water even with efficient aeration. Phillips and Brockway (1954) feel the best method for controlling ammonia is to reduce its rate of excretion by decreasing the metabolism of fish. They report a three-fold decrease in the accumulation of ammonia in tanks containing brook trout when the water temperature was reduced from 24 to 13 degrees C. The employment of ice during transport, therefore, not only reduces the consumption of oxygen by lowering metabolism, but also the excretion of poisonous wastes.

Bacterial buildup has been demonstrated by Vaas (1952) in closed system transport experiments. Bacteria are detrimental to transport operations both because of their respiration (which may place a serious demand on gas exchange) and also because of their waste products. Also, the handling that attends transport operations can be expected to penetrate the protective slime coat of many of the fish involved, thus making them more susceptible to infection, particularly where bacterial concentrations are high. Transport-induced bacterial and fungus infections may contribute significantly to post-planting mortality.

A few agents have been used to control bacteria and fungus during transport. Apparently the most commonly used bactericide is acriflavine. S. T. Snieszko (pers. comm.) of the U. S. Fish and Wildlife Service micro-biological laboratory at Kearneysville, West Virginia, reports that calphomycin (active ingredient oxytetracycline) shows promise for control of bacteria in transport water. Terramycin at a level of 50 milligrams per gallon is reported to be adequate for the prevention of bacterial disease during transport. Dr. Clark Hubbs of the University of Texas reports the use of methylene blue to remove *Ichthyophthirus* parasites during transport and the application of acriflavine for the control of fungus. McFarland and Norris (1958) found that "Tris-buffer" apparently inhibited bacterial growth in closed system transport, judging from the lack of decomposition of wastes and dead fish, the clarity of the water and its fresh odor in comparison to nonbuffered controls.

Although some headway has been made, the control of water quality by chemical means warrants more intense study.

Equipment for the Induction of Rheotaxis

Shall a current be induced in a transport tank? Commonly, currents have been induced in transport tanks to allow fish to orient and thus maintain position in the water mass (Horton, 1956). Such orientation is often considered beneficial, and for the alewife, essential (Conn. Bd. F. & G.). Carlson (1955) discusses the importance of careful adjustment of circulation rates in tuna bait tanks.

Objections to both the practice and the method of induction of rheotaxis in trout and perhaps other species appear cogent. In fish that do not need to swim to respire, or which do not possess strong schooling tendencies, the activity brought forth by forcing a fish to orient into a current seems undesirable. Certainly, if drugs are to be used, such induction of rheotaxis is in direct opposition to the beneficial effects of the drugs (McFarland, 1958). Current must be controlled at fairly low levels, particularly when hauling fish for long periods (Carlson, 1955) because it may induce unnecessary exertion.

Production of a current alone in tank water may not produce rheotaxis, even in species that possess the behavioral pattern. It may be necessary to provide eye markings on the interior tank walls so fish will receive stimuli indicative of current. Such marks may be simply vertical dark lines painted at intervals. In experimental work, dealing with swimming rate in fish, such marks are commonly used (Fry, 1957; Brett, Hollands and Alderdice, 1958), but they do not appear to be used in transport tanks. Instead fish must rely on the irregularities of the tank walls that are often inadequate for rheotactic orientation. Where large fish, but not necessarily heavy loads, are to be transported currents may be desirable since they aid in keeping the fish from scratching their sides on the tank walls or bottom. We have found this desirable at Marineland for actively swimming fish such as bonito *(Sarda chiliensis)*, Pacific mackerel *(Pneumatophorus diego)* and particularly albacore *(Thunnus germo)*.

USE OF DRUGS

Recently, considerable success has been achieved in increasing the weight per unit volume of trout that can be transported, by adding the barbiturate, sodium amytal, to the water (Reese, 1953; Calhoun, 1953). Under proper conditions (water temperature, aeration, etc.) the California Department of Fish and Game has been able to double or triple the weight of trout carried in airplane transport cans. Other drugs are reported to be useful, such as "Dormison" (Methylparafynol) but published results are wanting. Methane tricainesulfonate (M.S. 222), a narcotic that has received wide publicity as an anesthetic for cold-blooded vertebrates, has been investigated for transporting bluegills (*Lepomis macrochirus*) (Webb, 1958). Since his data show both positive and negative gains in the weight of fish normally transported, the usefulness of this drug for fish transport is difficult to interpret. Phillips and Brockway (1954) reported the effect of sodium amytal in reducing the rate of oxygen uptake and nitrogen excretion (as NH_3) in the brook trout, *Salvelinus fontinalis*, held in aquaria. Sodium amytal was found to have no effect in nonstarved fishes and was only as effective as reducing the water temperature, in previously starved fishes.

The beneficial effects of narcotics in transporting fish have been related to their sedative qualities (Reese, 1953) and to their action in possibly reducing the excretion of wastes (Calhoun, 1953), but surprisingly few actual data have accumulated. Recently, however, Nemoto (1957) has shown that sodium amytal at one-fourth grain per gallon is effective in reducing the rate of oxygen uptake of *Tilapia mossambica*. One of us (McFarland, 1958) has recently completed a study on the effects of several anesthetics on two species of marine teleosts. Results indicate that several drugs are useful for fish transport and produce their effects by decreasing the fishes' reactions to external stimuli. This results in a decreased activity metabolism and lowers the rates of oxygen consumption, of carbon dioxide production and of excretion of nitrogenous wastes, all of which can act as limiting factors in fish transport (McFarland, 1958; McFarland and Norris, 1958; Fry and Norris, ms.). The use of anesthetics to induce a decrease in these factors, however, can not be expected to increase the weight of fish per unit volume by more than two- or three-fold. If other means of reducing metabolism, such as temperature reduction (Prévost and Piché, 1939; Cuerrier, 1952), are also used, expected weight increases will be even less. The depth of anesthesia is crucial to success and concentrations necessary to maintain sedation have narrow tolerance limits (not more than twice the desired concentration).

Sodium amytal is antagonized by calcium ion (Onkst, Jacoby and Scarpelli, 1957; and McFarland, 1958). Its value for the transport of marine fishes is doubtful and the success reported with trout is probably achieved with relatively soft water. In fresh water, chelating agents such as citrate ion may be used to counteract this calcium antagonism but are not effective in sea water. Also the conflicting results reported by Webb (1958) for M.S. 222 are probably the result of metabolic lability of this compound.

Three anesthetics, methylparafynol, tertiary amyl alcohol, and chloral hydrate, should find wider use since they are effective in both fresh and salt water, are of long action (24-48 hours), are easily measured and are inexpensive and easily obtained. These anesthetics should find application in quieting large fishes that otherwise would damage themselves, in addition to allowing increases in weight of fish that can be carried. Some success has been attained with them at Marineland of the Pacific in attempts to transport such actively swimming fishes as albacore (*Thunnus germo*).

OSMOTIC PROBLEMS

Both fresh and salt water teleosts must continually expend energy to maintain their body fluids in a constant osmotic state. The body fluids of marine teleosts are hypotonic to the sea water that surrounds them, and hence they must constantly combat desiccation through the permeable surfaces of the gills. The situation is reversed for fresh water forms since they must combat imbibition of water. A small, but perhaps significant portion of the energy consumed to maintain basal metabolism in fishes goes toward maintaining this internal osmotic balance (Bateman and Keys, 1933; Potts, 1954; Wolschlag, 1957). If this energy expenditure can be reduced, oxygen consumption will drop as will waste production.

The most obvious approach to this problem is to place fish in water that is isotonic to their blood, but little work has been done on this subject. The findings of Brock and Takata (1955) on *Stolephorus purpureus* in various concentrations of sea water are not completely clear cut, but seem to indicate a significant increase in viability in isotonic solutions during transport and handling operations. *S. purpureus* is a species with large deciduous scales and is extremely susceptible to injury from handling. Hence the effects noted by Brock and Takata probably involve osmosis through breaks in the slime coating of the body as well as through the gills of the experimental fish. Such handling injuries are thought responsible for a large percentage of mortality incurred during bait hauls on Japanese tuna boats (Suehiro, 1933).

Many marine teleosts can be transferred gradually to water of salinities as low as about 10 percent sea water, but most will not survive much below this level. The concentration of salts in most fish bloods, both salt and fresh, is around 10 to 12 parts per thousand (Prosser et al., 1950). Hence if fish are hauled in 40 to 50 percent sea water, osmotic work should be largely eliminated and the extra stress imposed by loss of scales or by breaks in the slime coat greatly alleviated. The major drawback to the use of isotonic solutions is the necessity of transferring fish in stages both into and out of the transport water. It may be found that such step-wise transfer is not necessary for certain species and also that only partial dilution or concentration toward isotonicity will be beneficial. The whole subject needs investigation.

LOADS AND DISTANCES

Some quantitative data are available on the weight-per-unit-volume of fish that have been carried with various types of equipment. Most trout transporting agencies normally operate between 0.5 and 1.5 pounds of fish per gallon. At such levels, runs commonly cover 200 to 500 miles. The State of Montana Department of Fish and Game reports regular hauls at one of the highest levels of any reporting agency; 2.5 pounds of fish per gallon, using a truck equipped with an agitator with perforations along the heels of the blades (Stubblefield, Lefevre and Smart, 1949). A new spray-type unit of the California Department of Fish and Game described by Macklin (1959) is reported to hold successfully as much as 600 pounds of trout in 150 gallons of water in a standing test (4 lbs./gal.). This is by far the highest capacity reported. The standard Venturi aerated 1,590-gallon tanker used by the California Department of Fish and Game hauls 1.3 pounds of trout per gallon using sodium amytal sedation. The Missouri Goldfish Hatchery reports hauling 2 pounds per gallon of goldfish using agitator aeration.

The only figure available for normal loads carried by anchovy bait boats was calculated for a vessel operating out of Long Beach, California utilizing a 2,240-gallon tank. At a recirculation rate of once in seven minutes, one-half pound per gallon of water is normally carried without undue loss.

Horton (1956) found that post-planting mortality of rainbow trout (*Salmo gairdneri*) was less after transport in moderately crowded con-

ditions (1.10 percent at 1.2 pounds per gallon) than in less densely packed hauls (2.20 percent at 1.0 pound per gallon).

The longest truck haul reported to us is that made by the New York Aquarium, hauling various marine species. Christopher Coates, the director of the aquarium, reported that some of their runs start at Key West, Florida, refresh water at Marathon, Florida, and then continue without further addition of new water to New York. This last leg of the journey covers approximately 1,650 miles. Losses are reported as very low. The fish are held in several diffuser-aerated fiberglass coated plywood tanks. The longest run that has been attempted by Marineland of the Pacific started near Guaymas, Sonora, Mexico, and covered slightly more than 1,000 miles.

PRETREATMENT OF FISH

A standard procedure in the transportation of fishes appears to be an initial period of starvation. Not only does this materially reduce the quantity of regurgitated material that can contribute to pollution, but it also seems to assist in making the fish more resistant to temperature fluctuations and handling injury.

The importance of pretreatment with drugs (McFarland, 1958) is heavily underscored by the work of Black (1955, 1957a-c) and Black and Barrett (1957) who demonstrated the build-up of high concentrations of lactic acid by fish during periods of high activity. Such an oxygen debt is paid off very slowly by fish, in comparison with mammals. Thus the initial shock of handling and introduction into the transport tank may induce strong physiological stresses (Haskell, 1941) which may last during the entire haul, and quite possibly contribute to post-planting mortality (Schuck, 1948, Horton, 1956).

Sharp temperature fluctuations that sometimes occur during planting at the instant of transfer from tank to stream, are thought to contribute to post-planting mortality (Copeland, 1947).

DISCUSSION

This poll of various agencies and individuals indicates first, that virtually all fish transportation equipment in use today has been developed by trial and error. The amount of controlled experimental work that has been directed toward transportation problems is small.

A second conclusion, that stems directly from this empirical approach, is that many of the variables important to the success of transport have often been held just below critical levels. There is considerable room for improvement in the efficiency of water quality control and in the design of aeration devices. Rather simple chemical analyses prior to and during the design and construction of the various components of transport equipment would serve to develop greater efficiency.

The design of transport equipment should be dictated primarily by the need of reducing physiological stress in the fish, and secondarily by such factors as the shape of truck beds or hauling capacities of certain trucks. An important discussion for fisheries workers, on the implications of physiological stress upon fish has been presented by Brett (1958). He has subdivided environmental stresses into two cate-

gories; *discriminate* and *indiscriminate stresses*. Discriminate stresses are defined as those that apply at any one time to individuals singly, while indiscriminate stresses are those affecting every member and that are not discrete in action. These distinctions are important to thinking about stresses during transport. For example if an indiscriminate stress produces death or serious debility of a few fish during a transport operation it means that the remainder of the fish are in various lower, but perhaps serious degrees of stress. Indiscriminate stresses are produced by such factors as extreme temperatures, low oxygen, or toxic substances. Discriminate stresses are apt to be produced by injury, disease or parasitism, and may affect only a few of the fish during transport.

The physiological stresses for fish, occurring during transport, have been partially indicated by McFarland and Norris (1958) and reviewed more extensively by Fry and Norris (ms.) and by McFarland (1958). The problems of transport are not limited to the time of hauling alone. The treatment of fish prior to transport and the latent effects of transport upon fish must also be considered as part of the problem. For example, Horton (1956), Miller (1952), Saltzman (1953), Stroud and Bitzer (1955), and Wales (1954) all report significant post-transport mortality in game fish.

The factors that we consider to be of prime importance to transport are listed and discussed in the following paragraphs.

Activity Relationships

Very little information is now available that relates to the level of activity metabolism produced by crowding fish or from water quality factors. However, Haskell (1941) has shown that the greatest periods of activity usually occur immediately following introduction of fish into transport units.

Pink salmon, *Oncorhynchus gorbuscha*, forced to maximum activity showed little if any increase in heart rate (Black, 1957c). Information on stroke volume, or the amount of blood pumped through the heart per beat is limited (Mott, 1951). This is particularly true for fishes during periods of activity. Coupled with the limitations of the branchial system of fishes (Fry, 1957), the inefficiency of the circulatory system undoubtedly severely restricts the amount of oxygen that can be transported to the tissues in a given time. Fry (1957) has shown that the active metabolism of fishes does not exceed the standard metabolism more than four or five times. McFarland (1958) suggests that the restrictions imposed by the circulatory and branchial systems in supplying oxygen to the body tissues probably determine these limits. Such morphological limitations when compounded with indiscriminate physiological stresses, such as increased CO_2 and wastes, impose severe restrictions to successful transport of living fishes.

Because of the slow recovery of fishes from periods of unusually intense activity (probably due to the inefficiencies mentioned above), every possible means should be taken to reduce activity to fairly low levels during all phases of handling and transport (Haskell, 1941). Some data are available relating to the effects of temperature upon activity (Fry, 1957). In general, temperature reduction during trans-

port, as commonly employed with trout, effectively reduces the activity metabolism. Similar reductions are produced by narcotics. However, pretreating the fish with anesthetic is necessary if maximum decreases in activity metabolism are to take place during the initial phases of transport (McFarland, 1958).

Respiratory Relationships

The critical feature in the supply of oxygen during transport is not necessarily the concentration in the transport water but the level in the blood and tissues of the fish. High concentrations may be present in the transport water while fish are dying for lack of oxygen at the tissue level (McFarland, 1958). The effects of environmental factors upon the loading tension of fish blood (Bohr and Root effects) need to be carefully considered in the design of aerating and water quality control gear (McFarland and Norris, 1958). Not only must oxygen levels be adequate but carbon dioxide and waste product levels must be kept low enough to allow sufficient oxygen uptake.

Osmotic Relationships

Basal metabolism results from the sum total of processes that are just sufficient to maintain the animal with no excess activity. Fry (1957) has used the term "standard metabolism" to signify this level of maintenance while he uses "routine metabolism" to signify the average metabolism during a 24-hour period. One factor increasing each of these metabolic levels is the osmotic work that is performed by the fish to maintain the salt concentration of its blood. As has been discussed earlier, if this stress is removed or alleviated by carrying the fish in isotonic water or as nearly so as possible, greater loads may possibly be carried with lower mortality.

Temperature Relationships

Temperature increases result in increases of basal metabolic rates throughout the biokinetic range. Temperature changes often produce variations in the oxygen loading characteristics of fish blood (Black, 1940; Fry, 1957). Temperature also affects the solubility of oxygen in water. With these facts in mind it is interesting that Horton (1956) found post-planting mortality to be significantly lower in groups of trout hauled at lower temperatures than those hauled in warmer water.

The thermal tolerance polygon of Fry, Brett and Clawson (1942) expresses the viable thermal range for a given species of fish (Figure 7). Knowledge of such data for each species will assist materially in selection of the proper temperature regime for transport. Such temperature data should be made available for the major game fish species. Curves for standard metabolism and maximum activity over a range of temperatures, when combined with data from the thermal polygon should serve as guides for the selection of the best temperatures for transport.

Water temperature reduction alleviates transport problems in much the same manner as narcosis, by reduction of metabolic level.

TABLE 1

Characteristics of Some American Fish Transport Gear

Agency	Capacity of tanks or tanker (gals.)	Predominate species hauled	Max. fish weight lbs./gal.	Maximum distance (miles)	Aeration type	Construction material	Temperature control	Power	Chemical treatment	Tank shape	Aeration gas
New York Cons. Dept.	110	trout	.99	- - -	diffuser	plywood, steel	- - -	none	- - -	rect.	oxygen
New York Aquarium	320	various marines	.25	1,650	diffuser	plywood	- - -	compressor	- - -	rect.	air
New Mexico Dept. G. & F.	600	trout	1.2	- - -	Venturi	- - -	- - -	gasoline engine	- - -	elliptical	air
Nevada F. & G. Comm.	1,000	trout	1.4	500	spray and	steel	- - -	gasoline	- - -	- - -	air
	300	trout	1.9	500	Venturi	steel		engine			
Conn. Bd. of F. & G.	ca. 400	alewife	ca. 1 lb.	- - -	- - -	steel	- - -	gasoline engine	- - -	elliptical	air
Calif. Dept. F. & G.	1,500	trout	1.3	500	Venturi	steel	refrig. & glass wool	electric	sodium amytal	oval cylinder	air & stand-by oxygen
Calif. Dept. F. & G.	150	trout	4	ca. 150	Venturi and spray	steel	none	gasoline	- - -	rect.	air
New Jersey Dept. Cons.	1,152	trout	- - -	150	spray	steel	- - -	- - -	- - -	rect.	air
Montana Dept. F. & G.	900	trout	1.1	250	diffuser	fiberglass	Styrofoam insulation & refrig.	propane	- - -	rect.	oxygen

ACKNOWLEDGMENTS

Any such survey as this must rely upon help from a large number of people. We have received wholehearted co-operation from nearly every one of the 96 agencies and individuals polled. We are very grateful for this assistance. For special assistance and advice during the preparation of the manuscript we wish to thank Dr. Alex Calhoun and Mr. Bruce Kimsey of the California Department of Fish and Game. Mr. Vernon Brock of the Pacific Oceanic Fisheries Investigation has given assistance in several ways. Dr. Earl Herald of the Steinhart Aquarium has helped by supplying reference material which was previously unknown to the authors.

As some measure of return for the time and thought which our contributors have given us, we hope that this survey will stimulate development of better fish transportation techniques used by these persons and agencies.

We wish to thank Mrs. Muriel Johnson for her patient assistance during preparation of the manuscript, and to Patricia Powell for her help with bibliographic problems. We also wish to express our appreciation to Philip Schuyler for preparation of the diagrams.

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THE MORRO BAY OTTER TRAWL AND PARTY BOAT FISHERIES AUGUST, 1957 TO SEPTEMBER, 1958[1]

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INTRODUCTION

The Morro Bay otter trawl and party boat fisheries exhibited a remarkable growth from 1952 to 1957. This growth was most spectacular in the trawl fishery where rockfish catches increased 40-fold from 1952 to 1955. Since 1955 the rockfish catches have remained near 3,000,000 pounds. The 1957 rockfish catch of 2,700,000 pounds was contributed by an estimated 1,140,000 rockfish.

The sport fishery from party boats in this area was characterized by a somewhat less spectacular growth. Nevertheless, statistics show the rockfish catch has more than doubled in recent years, from 185,398 in 1954 to 341,099 rockfish in 1957.

Although rockfish are not the only species taken, they make up about 90 percent of the sport and commercial catches. Thus, they serve as good indicators of the fisheries as a whole.

The increased catches, especially by the trawl fleet, caused great public concern that commercial trawling would have a detrimental effect on the sport fishery of the area. On May 28, 1957, the State Senate passed Resolution No. 150, calling for an interim study of the situation. The Senate Interim Committee assigned the California Department of Fish and Game the responsibility of determining facts for evaluating the effects of the two fisheries.

Because of the recentness of the expansion of these fisheries at Morro Bay, very little was known concerning species composition of the landings, and, for the trawl fishery, there was no information about amounts and kinds of trash or unsalable fish discarded at sea. Such information is basic in evaluating competition between commercial trawling and sport fishing, and a one-year program was initiated by the Department to obtain this information. A minimum of one year was needed to gain a clear picture of the fisheries in the various seasons.

The study was assigned to two projects within Marine Resources Operations. The Trawl Investigation received the responsibility for determining the necessary information about the trawl fishery, while the Northern California Marine Sport Fish Survey, the Dingell-Johnson project F-12-R was to determine facts about the party boat sport

[1] Submitted for publication August, 1959. Portions of this work were performed as part of Dingell-Johnson Project California F-12-R, "Northern California Marine Sport Fish Survey," supported by Federal Aid to Fish Restoration Funds.
A synopsis of this report was published in "Progress Report to the Legislature by the Senate Interim Commitee on Fish and Game" 1959.

fishery. The trawl survey ran from August, 1957, through July, 1958. The sport fish survey started later, running from October, 1957, through September, 1958. This report is based on the information gathered by these two projects.

More than 70 species of fish belonging to 28 families were examined during these surveys of the fisheries. Their scientific and common names have been listed in Table 1 and henceforth all references will be by vernacular only.

TABLE 1

Fishes Observed in the Sport and Commercial Catches at Morro Bay, 1957-1958

		T-caught by trawlers	P-caught by party boats
FAMILY HEXANCHIDAE—Cowsharks			
Sixgill cowshark	*Heranchus griseum* (Bonnaterre)	–	T
FAMILY SCYLIORHINIDAE—Catsharks			
Filetail catshark	*Parmaturus xaniurus* (Gilbert)	–	T
FAMILY CARCHARHINIDAE—Requiem sharks			
Blue shark	*Prionace glauca* (Linnaeus)	–	T
Soupfin	*Galeorhinus zyopterus* Jordan & Gilbert	–	T
FAMILY SQUALIDAE—Dogfishes			
Dogfish	*Squalus acanthias* Linnaeus	–	T
FAMILY RAJIDAE—Skates			
California skate	*Raja inornata* Jordan & Gilbert	T	T
Big skate	*Raja binoculata* Girard	–	T
Longnose skate	*Raja rhina* Jordan & Gilbert	T	T
Sandpaper skate	*Raja kincaidi* Garman	–	T
Monterey skate	*Raja montereyensis* Gilbert	–	T
FAMILY TORPEDINIDAE—Electric rays			
Electric ray	*Torpedo californica* Ayres	–	T
FAMILY CHIMAERIDAE—Chimaeras			
Ratfish	*Hydrolagus colliei* (Lay & Bennett)	–	T
FAMILY SALMONIDAE—Trouts			
King salmon	*Oncorhynchus tshawytscha* (Walbaum)	–	P
FAMILY MERLUCCIIDAE—Hakes			
Pacific hake	*Merluccius productus* (Ayres)	–	T
FAMILY BOTHIDAE—Left-eyed flounders[1]			
Pacific sanddab	*Citharichthys sordidus* (Girard)	–	T
FAMILY PLEURONECTIDAE—Right-eyed flounders[1]			
Arrowtooth halibut	*Atheresthes stomias* (Jordan & Gilbert)	T	T
Pacific halibut	*Hippoglossus stenolepis* Schmidt	T	T
Slender sole	*Lyopsetta exilis* (Jordan & Gilbert)	T	T
Petrale sole	*Eopsetta jordani* (Lockington)	–	T
Curlfin turbot	*Pleuronichthys decurrens* Jordan & Gilbert	–	T
Hornyhead turbot	*Pleuronichthys verticalis* Jordan & Gilbert	T	T
English sole	*Parophrys vetulus* Girard	–	T
Dover sole	*Microstomus pacificus* (Lockington)	–	T
Rex sole	*Glyptocephalus zachirus* Lockington	–	T
FAMILY ATHERINIDAE—Silversides			
Jacksmelt	*Atherinopsis californiensis* Girard	–	P
FAMILY CARANGIDAE—Jacks			
Pacific jack mackerel	*Trachurus symmetricus* (Ayres)	–	T & P
FAMILY STROMATEIDAE—Butterfishes			
California pompano	*Palometa simillima* (Ayres)	–	T
FAMILY SCOMBRIDAE—Mackerels			
Pacific mackerel	*Pneumatophorus diego* (Ayres)	–	P

TABLE 1—Continued

		T-caught by trawlers	P-caught by party boats
	FAMILY SCIAENIDAE—Croakers		
White croaker	*Genyonemus lineatus* (Ayres)	–	P
White seabass	*Cynoscion nobilis* (Ayres)	–	P
	FAMILY EMBIOTOCIDAE—Surfperches		
Pink seaperch	*Zalembius rosaceus* (Jordan & Gilbert)	–	T
	FAMILY SCORPAENIDAE—Rockfishes		
Shortbelly rockfish	*Sebastodes jordani* Gilbert	–	T
Boeaccio	*Sebastodes paucispinis* (Ayres)	–	T & P
Chilipepper	*Sebastodes goodei* Eigenmann & Eigenmann	–	T
Widow rockfish	*Sebastodes entomelas* (Jordan & Gilbert)	–	T & P
Speckled rockfish	*Sebastodes ovalis* Ayres	–	T
Blue rockfish	*Sebastodes mystinus* (Jordan & Gilbert)		P
Black rockfish	*Sebastodes melanops* (Girard)		P
Yellowtail rockfish	*Sebastodes flavidus* Ayres	–	T & P
Olive rockfish	*Sebastodes serranoides* Eigenmann & Eigenmann	–	P
Canary rockfish	*Sebastodes pinniger* (Jordan & Gilbert)	–	T & P
Vermilion rockfish	*Sebastodes miniatus* (Jordan & Gilbret)	–	T & P
Cow rockfish	*Sebastodes levis* (Eigenmann & Eigenmann)	–	T & P
Dark-blotched rockfish	*Sebastodes crameri* Jordan	–	T
Brown rockfish	*Sebastodes auriculatus* (Girard)	–	P
Stripetail rockfish	*Sebastodes saxicola* (Gilbert)		T
Blackgill rockfish	*Sebastodes melanostomus* Eigenmann & Eigenmann	–	T
Splitnose rockfish	*Sebastodes diploproa* (Gilbert)	–	T
Flag rockfish	*Sebastodes rubrivinctus* (Jordan & Gilbert)	–	P
Whitebelly rockfish	*Sebastodes vexillaris* (Jordan & Gilbert)		P
Bronzespotted rockfish	*Sebastodes gilli* Eigenmann & Eigenmann	–	P
Greenstriped rockfish	*Sabastodes elongatus* (Ayres)	–	T & P
Rosy rockfish	*Sebastodes rosaceus* Jordan & Gilbert	–	P
Greenspotted rockfish	*Sebastodes chlorostictus* (Jordan & Gilbert)	–	P
Pink rockfish	*Sebastodes eos* (Eigenmann & Eigenmann)	–	T
Starry rockfish	*Sebastodes constellatus* (Jordan & Gilbert)	–	P
China rockfish	*Sebastodes nebulosus* (Ayres)		P
Gopher rockfish	*Sebastodes carnatus* (Jordan & Gilbert)	–	P
Black-and-yellow rockfish	*Sebastodes chrysomelas* (Jordan & Gilbert)	–	P
Treefish	*Sebastodes serriceps* (Jordan & Gilbert)		P
	FAMILY ANOPLOPOMATIDAE—Sablefishes		
Sablefish	*Anoplopoma fimbria* (Pallas)	–	T
	FAMILY HEXAGRAMMIDAE—Greenlings		
Greenling seatrout	*Hexagrammos decagrammus* (Pallas)	–	P
	FAMILY OPHIODONTIDAE—Lingcods		
Lingcod	*Ophiodon elongatus* Girard		T & P
	FAMILY ZANIOLEPIDAE—Combfishes		
Shortspined combfish	*Zaniolepis frenata* Eigenmann	–	T
	FAMILY OXYLEBIIDAE—Convictfishes		
Convictfish	*Oxylebius pictus* Gill	–	T
	FAMILY COTTIDAE—Sculpins		
Cabezon	*Scorpaenichthys marmoratus* (Ayres)	–	P
Threadfin sculpin	*Icelinus filamentosus* Gilbert		T
Sculpins	Not identified to species		T
	FAMILY AGONIDAE—Poachers		
Poachers	Not identified to species	–	T
	FAMILY BATRACHOIDIDAE—Toadfishes		
Northern midshipman	*Porichthys notatus* Girard	–	T
	FAMILY ZOARCIDAE—Eelpouts		
Eelpouts	Not identified to species	–	T
	FAMILY OPHIDIIDAE—Cusk-eels		
Spotted cusk-eel	*Otophidium taylori* (Girard)	–	T

[1] Flatfish were also taken by the party boats but were not identified to species.

OBJECTIVES

Since this study was undertaken by two projects with differing commitments and available manpower, somewhat different objectives had to be set by each project.

Those set by the trawl investigation for the study of the Morro Bay trawl fleet were:

(1) To determine the species of fish taken.
(2) To determine for each species the poundage saved for marketing as well as the poundage discarded at sea.
(3) To determine the lengths and weights of species taken, especially those that could be considered controversial.

The sportfish investigation, limited by previous manpower commitments, set as its objective:

(1) To determine the composition of the party boat catch by numbers and species.

SAMPLING PROGRAM

Trawl Survey

Trawl fishermen sort their catch at sea and discard unmarketable fish before returning to port. Therefore, to determine the true composition of catches it was necessary to sample as they were made. Through the co-operation of the fishing industry arrangements were made for Marine Resources Operations biologists to accompany fishermen to fishing grounds and examine catches.

While aboard vessels, attempts were made to weigh all fish taken and to measure controversial species discarded. Occasionally these activities had to be modified to fit in with operations of the vessels when unusual loads were encountered. As a result of such modifications, fish were sometimes only counted by species, and weights estimated from numbers counted. Another modification of technique used, when exceptionally large amounts were discarded, involved measuring and weighing only part of the load. Data from a sample such as this were considered representative of the remainder of the discard in that particular haul.

Marketable fish seldom were measured or weighed aboard ship. Total weights marketed on a particular day were taken from market receipts and pro-rated among individual drags. Composition of marketed rockfish by species was determined from market sampling, when possible, or by estimation at the time of the catch. Market samples were also used to determine size, sex, and maturity of rockfish.

Fish lost during the hauling in of nets were considered part of the discard. Weights of these were estimated by species from numbers counted floating in the water. Weights thus obtained were added to those of species discarded after nets had been brought on board.

Sport Fishing Survey

Sport fishermen on party boats normally keep everything they catch. This considerably simplified the sampling procedure for complete catches could be sampled when boats returned to port. As the fisher-

men debarked, their catch would be dumped into a sampling box and tallied.

In most cases, it was possible to count by species all fish caught. Occasionally, in mixups of unloading and milling around the dock, some fishermen would depart before their fish could be tallied. There was a voluntary agreement on the part of all party boat operators to allow samplers to detain departing fishermen for sampling. However, for good public relations, those fishermen desiring to depart quickly were not detained. Species composition was the only objective, so it was not necessary to make adjustments if only a portion of the fishermen was sampled for catch. During the study over 90 percent of the fishermen encountered were checked.

THE MORRO BAY FISHERIES

Trawl Fishery

Trawlers from Morro Bay work in an area from just north of Pt. Piedras Blancas south to the vicinity of Pt. Buchon in depths ranging from 45 to 160 fathoms (270 to 960 feet). This area was not fished with equal intensity throughout; the great majority of fishing was done between Morro Bay and Pt. Piedras Blancas in depths of 70 to 115 fathoms (420 to 690 feet).

The major objective was rockfish, and the principal grounds extending from Morro Bay north to Pt. Piedras Blancas received about 90 percent of the fishing effort. An area farther north was fished only occasionally because of the long trip required to reach it (about five hours of running time each way).

At times, to fill market orders, boats went out to take flatfish in one or the other of two general areas. The principal area was well south of Morro Bay off of Pt. Sal or Pt. Arguello. This was primarily a deep-water fishery carried out in around 150 fathoms (900 feet) although fishing was also done in adjacent inshore areas. The secondary area was inshore from the rockfish grounds. Seeking flatfish in these two areas occupied about 10 percent of the total trawling time.

By law, trawl vessels are required to operate at least three miles from shore. This limits them to depths of over 50 fathoms (300 feet) in areas adjacent to Morro Bay.

During the course of this study the number of active vessels varied from one to five (Figure 1). The main cause of these fluctuations was the lure of albacore. Of the four boats trawling in August, 1957, two—the *Franklin* and the *Friendship*—turned to albacore fishing before August, 1958. A third vessel the *Westwind*, left the area in April, 1958. The *Evelyn II.*, trawled only from February to mid-June, 1958, and then switched to albacore fishing leaving only the *Mel-Don* trawling at Morro Bay at the end of the study. The *Franklin* and *Friendship* expected to return to trawling after the 1958 albacore season.

Two other vessels operated from Avila but since they were fishing exclusively to the south, below Pt. Buchon, they were not considered in this study. Both of these boats, the *Katherine* and *Jack Jr.* went albacore fishing in early June, 1958.

The amount of time a boat fishes in any month depends largely upon weather. Heavy swells make it particularly difficult to trawl since they

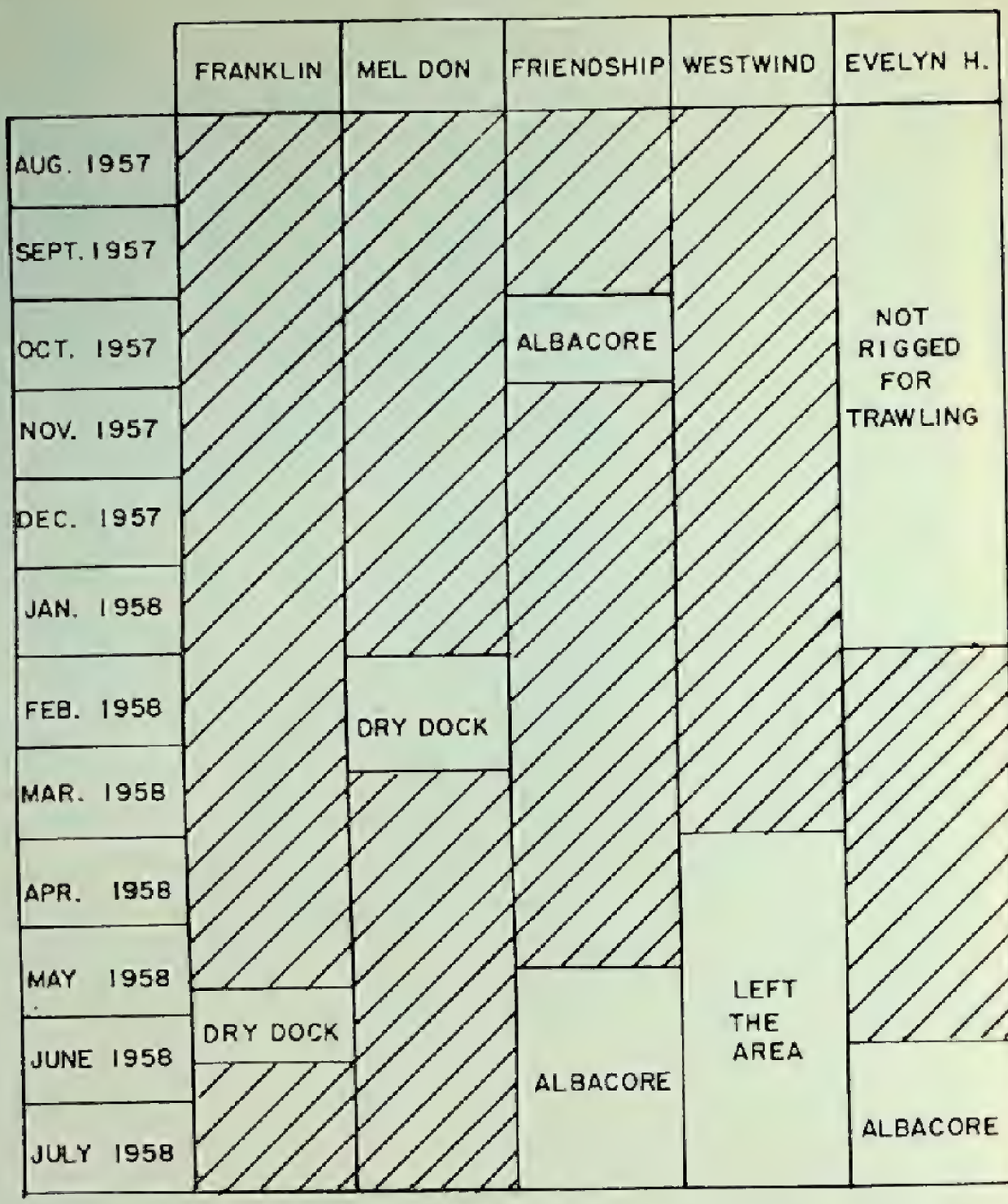

FIGURE 1. Activities of Morro Bay trawlers during August, 1957, through July, 1958. The shaded areas represent periods during which vessels were trawling.

cause jerking and relaxing of gear. During bad storms, wind and breakers at the entrance to Morro Bay are dangerous and keep boats in. Lesser storms also create some danger, however, the channel can be navigated during daylight hours. Fishing time is curtailed considerably when the fisherman is forced to leave and return during daylight hours.

Market demands can also cut into fishing time although at Morro Bay supply and demand seemed to be in a fairly good state of balance.

Finally, engine breakdowns and torn nets make vessels inactive until repairs are made.

The Party Boat Fishery

The Morro Bay party boat fishery operates all year. However, the majority of sportfishing effort is expended during the vacation months of June, July and August. During January and February, fishing drops to about one-tenth its midsummer level. In August, 1958, 3,858 anglers utilized the party boat facilities of this area.

Rockfish are the major attraction of this fishery. In 1957 this area produced over half of Northern California's rockfish catch and was the leading rockfish area in the State. Rockfish accounted for 341,099 of the 371,090 fish taken in the Morro Bay area in 1957.

Twenty-six party boats were operating in the Morro Bay-Avila-Cayucos area, with 18 at Morro Bay itself. Both live and dead bait are available and salt water fly fishing (actually a form of jigging with a cloth-covered hook) has lately become popular.

The boats usually fish within 10 miles of the harbor. The most popular spots are offshore shallow banks and inshore kelp beds. Fishing depth varies from 30 feet around kelp beds to 100 feet on the offshore banks, although they may occasionally fish in depths up to 300 feet. Boats often fish the deeper areas first, trying for larger species, and move into shallow areas later in the day to fill out limits on smaller kinds of rockfish.

METHODS

Trawl Survey

During this study 64 drags were observed on 24 trips with Morro Bay trawlers. Twenty-two of these trips were made to the heavily fished rockfish grounds north of Morro Bay, and one trip was made to each of the flatfish areas. Five individual drags were made during the two flatfish trips.

Record forms were prepared aboard the vessels for each of the 64 drags. Each species was listed by the total weight landed and total weight discarded. The name of the boat, type of net, length and location of the drag, and weather conditions were also noted. These forms comprised the basic data sheets for the trawl survey.

Total weight by species was initially kept separate for rockfish and flatfish drags. However, to give an overall picture of catch composition at Morro Bay, all 64 drags were combined. The total weight of a species caught during the year was then divided by the number of drags to give the weight of that species per drag. This average weight per drag is the basis for the discussions of individual species.

To further facilitate discussion, species have been grouped into five categories: rockfish, flatfish, lingcod, sharks and rays, and miscellaneous and each category discussed separately.

The various species making the catch fit into four desirability classes:

Class I: Very desirable. Large in size or of high market value. Rarely discarded. Examples: bocaccio and petrale sole.

Class II: Less desirable. Smaller in size or of negligible market demand. Smaller specimens sometimes discarded. Example: rex sole.

Class III: Generally undesirable. Almost always of small size or of poor market quality. Larger specimens sometimes marketed. Examples: greenstriped rockfish and curlfin turbot.

Class IV: Undesirable. Of small size or no market demand. Always discarded. Examples: stripetail rockfish and longnosed skate.

These four classes are arbitrary, reflecting marketing conditions existing in the Morro Bay area. The same species may be in an entirely different class in another area. For example, sablefish are Class III at Morro Bay but Class I in northern California.

Sportfish Survey

Catches of 890 anglers were examined in the course of this survey. Information was summarized for the year and the composition of the catch determined. Composition has been expressed as percentage by number and as catch per angler day.

The sampling was done randomly to insure that boats using different kinds of bait were sampled in proportion to their importance in the fishery. In this way the catch of one boat or one type of bait could not bias the results.

To facilitate comparisons with the trawl catch the same five categories are used in discussions of the sport catch. These categories are rockfish, flatfish, lingcod, sharks and rays, and miscellaneous.

No desirability classes were obvious for the sport fishery. The desirability of any species varied, depending on the preferences of the individual angler. In general, the larger species were preferred, although no fish was rejected because of its size.

ROCKFISH

Trawl Survey

Rockfish were by far the most important group of fish caught by the trawlers at Morro Bay. They represented 82.2 percent of the total weight of the catch (Figure 2), and weighed 1,731.3 pounds in an average drag of 2,106.9 pounds. During the sampling at sea, 15 species were taken, some frequently and in large amounts. Others were represented in the 64 drags by only one or two fish. (Table 2.)

Of the trawl caught rockfish 98.7 percent, by weight, were Class I species. The remaining 1.3 percent was in either Class III or Class IV. The very high percentage of desirable rockfish indicates a small discard. Actually, the discard amounted to 30.5 pounds per drag or 1.8 percent of the rockfish catch. The discard was 31.5 percent Class I, 11.1 percent Class III, and 57.4 percent Class IV. Although 31.5 percent of the rockfish discard was very desirable fish, it was the very large proportion of Class I rockfish in the catch that brought this about. Actually, by weight, only 0.6 percent of the desirable rockfish caught were discarded while 75.6 percent of the Class III and 100 percent of the Class IV rockfish were discarded. The marketed portion of the rockfish catch contained 99.9 percent Class I and 0.1 percent Class III rockfish.

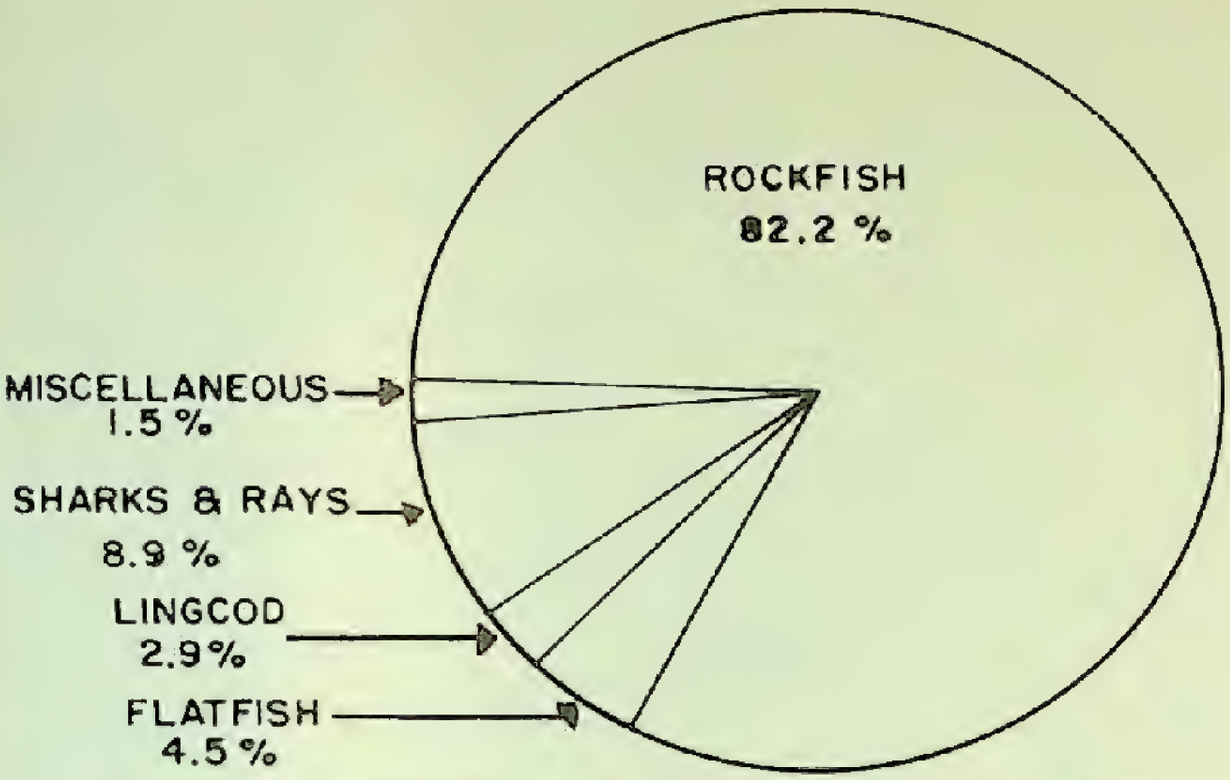

FIGURE 2. Composition of the Morro Bay trawl catch. Percentages are based on weight.

TABLE 2

Species of Rockfish Taken in 64 Drags Off Morro Bay—August, 1957 to July, 1958

Species	Caught			Discarded			Number of occurrences (drags)	Desirability
	Total pounds	Percent of total rockfish	Average pounds per haul	Total pounds	Percent of species total	Average pounds per haul		
Bocaccio	72,732	65.6	1,136.4	315	0.4	4.9	64	I
Chilipepper	35,257	31.8	550.9	295	0.8	4.6	60	I
Stripetail rockfish	747	0.7	11.7	747	100.0	11.7	52	IV
Widow rockfish	687	0.7	10.7	5	0.7	0.1	17	I
Shortbelly rockfish	364	0.3	5.7	364	100.0	5.7	37	IV
Vermilion rockfish	302	0.3	4.7	–	0.0	–	13	I
Greenstriped rockfish	289	0.3	4.5	216	74.7	3.4	23	III
Speckled rockfish	275	0.2	4.3	–	0.0	–	1	I
Pink rockfish	66	0.1	1.0	–	0.0	–	7	I
Canary rockfish	42	–	0.7	–	0.0	–	9	I
Cow rockfish	33	–	0.5	–	0.0	–	3	I
Blackgill rockfish	5	–	0.1	–	0.0	–	2	I
Splitnose rockfish	3	–	–	3	100.0	–	2	IV
Dark-blotched rockfish	2	–	–	2	100.0	–	1	IV
Yellowtail rockfish	1	–	–	–	0.0	–	1	I
Total	110,805	100.0	1,731.3	1,947	1.8	30.4		

Ten species of rockfish are considered very desirable (Table 2). By far the most important of these are the bocaccio and chilipepper. These two made up 98.7 percent of the weight of Class I rockfish and were the principal market fish at Morro Bay.

Bocaccio and chilipepper are comparatively large fish. Market samples of 1,221 bocaccio and 1,044 chilipepper indicated an average total length of 482.7 mm. (19.0 inches) and 413.2 mm. (16.3 inches) respectively. Specimens too small to be marketed were rare in the catch. Fourteen unmarketable bocaccio and 39 unmarketable chilipepper averaged 307.1 mm. (12.1 inches) and 254.2 mm. (10.0 inches) total length, respectively.

The remaining 1.3 percent of very desirable rockfish consisted of eight species which showed up only sporadically. The more important of these were the widow and vermilion rockfish, which occurred in 17 and 13 of the 64 drags respectively. Together, they made up about three-quarters of the remaining Class I rockfish. They contributed 15.4 pounds to the average drag, compared to the almost 1,700 pounds contributed by the bocaccio and chilipepper.

Two more species, the canary and pink rockfish, were caught somewhat less frequently (nine and seven drags respectively). Together they contributed only 1.7 pounds in an average drag.

The remaining four desirable rockfish occurred in only one, two or three drags. The speckled rockfish was caught in only one drag, but in the comparatively large amount of 275 pounds. It is thus recorded as having contributed 4.3 pounds to the average drag. The cow, blackgill, and yellowtail rockfish together represented only 0.6 pounds in the average drag. The small amounts caught indicate their insignificance to the Morro Bay otter trawl catch.

No Class II and only one Class III rockfish entered the catch at Morro Bay. The Class III species was the greenstriped rockfish. This fish was generally discarded as an undesirable market species, but occasionally the larger specimens were retained. In the 23 drags in which it occurred, 74 percent by weight was discarded. It made up 4.5 pounds in an average drag. Greenstriped rockfish are comparatively small fish, attaining a maximum size of around 380 mm. (15 inches). The average size of 45 discarded and 11 marketed specimens was 251.8 mm. (9.9 inches) and 298.7 mm. (11.8 inches) respectively.

Four species are included in the Class IV or undesirable rockfish. Two of these, the stripetail and shortbelly rockfish, made up over 99 percent. These two attain maximum sizes of only 330 mm. (13 inches) and 305 mm. (12 inches) respectively, precluding their use as market fish. Measurements of 463 stripetail and 221 shortbelly rockfish averaged 195.6 mm. (7.7 inches) and 233.0 mm. (9.2 inches). They made up 1.0 percent by weight of the rockfish catch. They were quite numerous in the catch, in excess of 100 often occurring in a single drag. Stripetail rockfish were present in 52 drags, averaging 11.7 pounds per drag. Shortbelly rockfish were slightly less important, appearing in 37 drags and averaging 5.7 pounds per drag.

The remaining two species, the darkblotched and splitnose rockfish were placed in Class IV only because very few examples of each were taken and these were too small to be marketed. At Morro Bay they made up only 0.06 pounds in an average drag.

In summary, bocaccio and chilipepper were the only rockfish used extensively, and the remaining desirable rockfish accounted for a very minor portion of the catch. Undesirable Class III and IV rockfish were of minor importance in the total catch and were either small or rare fish of no commercial importance.

Sportfish Survey

Rockfish formed the greatest part of the party boat catch. They represented 93.4 percent of the number (Figure 3) and an estimated 85 percent of the weight of all fish taken. They accounted for 13.0 of 13.9 fish in the average daily catch-per-angler.

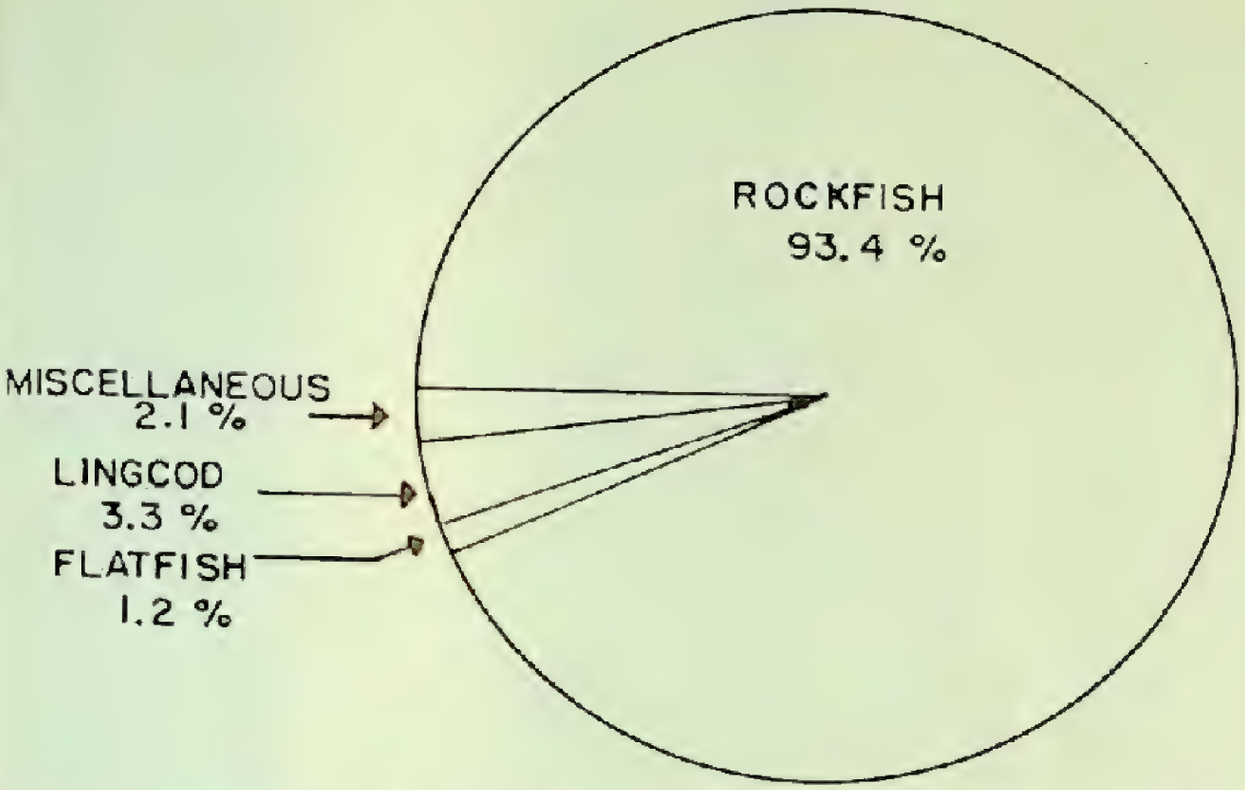

FIGURE 3. Composition of the Morro Bay party boat catch. Percentages are based on numbers.

The party boat rockfish catches had a varied composition, with several species appearing in significant amounts. All told, 21 species of rockfish were identified in the catches although some appeared only in very small quantities (Table 3).

The blue rockfish was the most important single species, accounting for 54 percent of the rockfish taken. It is found in abundance in shallow water and to depths of 300 feet. Blue rockfish thus form the backbone of the party boat industry and bear the brunt of fishing pressure. Catches of the blue rockfish averaged 7.0 fish per angler during the survey.

Olive rockfish were also very important, accounting for 16 percent of the rockfish caught. They supplied 2.1 fish to the anglers' daily bag. They are primarily a shallow water species, taken around kelp beds.

Olive and blue rockfish together made up almost the entire catch taken by ocean fly fishing. Boats using this method often had catches consisting exclusively of these two species.

After blue and olive rockfish, the importance of individual species tapered off. Yellowtail rockfish, vermilion rockfish and bocaccio each made up about 5 percent of the catch. These are largely taken in deeper

TABLE 3

Species Taken by 890 Party Boat Anglers at Morro Bay—October, 1957 to September, 1958

	Number taken	Percent of Rockfish	Percent of miscellaneous	Percent of total	Catch per angler
ROCKFISH	**11,664**	–	–	**93.4**	**12.99**
Blue rockfish	6,246	54.0		50.4	7.02
Olive rockfish	1,853	16.0		15.0	2.08
Yellowtail rockfish	652	5.6		5.3	0.73
Vermilion rockfish	563	4.9		4.6	0.63
Bocaccio	466	4.0		3.8	0.53
Canary rockfish	372	3.2		3.0	0.42
Whitebelly rockfish	361	3.1		2.9	0.41
Gopher rockfish	290	2.5		2.3	0.33
Widow rockfish	260	2.3		2.1	0.29
Rosy rockfish	140	1.2		1.1	0.16
Greenspotted rockfish	128	1.1		1.0	0.14
Starry rockfish	110	1.0		0.9	0.12
Greenstriped rockfish	26	0.2		0.2	0.03
China rockfish	25	0.2		0.2	0.03
Flag rockfish	20	0.2		0.2	0.02
Black rockfish	16	0.2		0.1	0.02
Cow rockfish	7	0.1		0.1	0.01
Black-and-yellow rockfish	3	–		–	
Treefish	3	–		–	–
Brown rockfish	2	–		–	–
Bronzespotted rockfish	1	–		–	–
Unidentified	20	0.2		0.2	0.02
FLATFISH	**142**	–	–	**1.2**	**0.16**
LINGCOD	**410**	–	–	**3.3**	**0.46**
MISCELLANEOUS	**266**	–	–	**2.1**	**0.30**
Jack mackerel	98		36.8	0.8	0.11
Greenling seatrout	69		25.9	0.5	0.08
Cabezon	58		21.8	0.5	0.07
White seabass	20		7.5	0.2	0.02
King salmon	7		2.6	0.1	0.01
Jacksmelt	5		1.9	–	
White croaker	2		0.8	–	–
Pacific mackerel	1		0.4	–	–
Unidentified	6		2.3	–	0.01
Total	12,382	100.0	100.0	100.0	13.91

water, and are prized because of their large size. Individually, they added 0.6 fish to the average daily take.

Canary, whitebelly, gopher, and widow rockfish were next in importance, individually contributing about 3 percent of the catch. Together they added 1.4 fish to the anglers' daily bag.

Rosy, greenspotted, and starry rockfish in combination made up another 3 percent of the numbers taken. They were of minor importance, however, supplying in total only 0.5 fish to the average anglers' daily bag.

The remaining nine species of rockfish taken were relatively rare. These nine, together with the unidentifiable rockfish, made up about 1 percent of the rockfish catch and contributed but 0.1 fish to the average daily take. These fish entered the landings sporadically and in small amounts. Because of their rarity they did not contribute significantly to the catch of the party boat fishermen.

Many kinds of rockfish contributed to the catch; however, it was the blue and the olive rockfish that stood out. Seven out of every 10 rockfish taken were these two species.

FLATFISH

Trawl Survey

Flatfish were taken both on the rockfish grounds, incidental to the rockfish catch, and on the flatfish grounds where the objective was flatfish. In reference to this study, about one-third of the flatfish were taken in the five drags on the flatfish grounds, and the remaining two-thirds were taken in the 59 drags on the rockfish grounds. As stated previously, all the fish taken in these two areas are being considered together.

As a group, the flatfish made up 4.5 percent of the total weight of the trawl catch (Figure 2), representing 94.4 pounds in an average drag of 2,106.9 pounds. Ten species were taken, the majority of these only rarely or in very small amounts (Table 4).

TABLE 4

Species of Flatfish Taken in 64 Drags Off Morro Bay—August, 1957 to July, 1958

Species	Caught			Discarded			Number of occurrences (drags)	Desirability
	Total pounds	Percent of total flatfish	Average pounds per haul	Total pounds	Percent of species total	Average pounds per haul		
Petrale sole	3,507	58.0	54.8	21	0.6	0.3	45	I
Rex sole	1,496	24.8	23.4	266	17.8	4.2	53	II
English sole	668	11.0	10.4	12	1.8	0.2	31	I
Pacific sanddab	257	4.3	4.0	257	100.0	4.0	7	IV
Curlfin turbot	35	0.6	0.6	29	81.1	0.5	12	III
Pacific halibut	30	0.6	0.5	–	0.0	–	1	I
Dover sole	22	0.4	0.4	16	71.1	0.2	10	III
Slender sole	18	0.3	0.3	18	100.0	0.3	12	IV
Hornyhead turbot	4	–	–	1	25.0	–	2	III
Arrowtooth halibut	4	–	–	4	100.0	–	2	IV
Total	6,041	100.0	94.4	621	10.3	9.7		

In weight, 94.4 percent of the flatfish catch was made up of the more desirable Class I and Class II species. Hence, the discard of flatfish was low, amounting to 10.3 percent by weight. The 89.7 percent of the catch marketed was composed of 77.0 percent Class I, 22.7 percent Class II, and 0.3 percent Class III fish. The 10.3 percent discarded was made up of 5.2 percent Class I, 43.3 percent Class II, 6.2 percent Class III, and 45.3 percent Class IV fish.

Two flatfish were considered very desirable. The most important, the petrale sole, made up 58.0 percent of the flatfish catch. They were the most desirable market species at Morro Bay, commanding the highest price of the commonly taken flatfish. The English sole was also an important and valued species, making up 11.0 percent of the flatfish

catch. Only very small specimens of these two were discarded, the discard for both being only 0.8 percent.

The average sizes of 201 marketed and eight discarded petrale sole were 382.4 mm. (15.1 inches) and 262.0 mm. (10.3 inches) respectively. English sole are somewhat smaller; the average length of 69 marketed specimens was 358.2 mm. (14.1 inches) while discarded specimens averaged 278.7 mm. (11.0 inches). The small number of discarded specimens was indicative of their rarity in the catch.

A single Pacific halibut was caught. This species is rare south of Monterey Bay and is not a normal part of the catch. The specimen taken measured 1,118 mm. (44 inches).

The only Class II flatfish was the rex sole. It is not as desirable as the preceding three flatfish because of its small maximum size. The average length of 446 marketed specimens was 332.6 mm. (13.1 inches). Rex sole shorter than 310 mm. (12.2 inches) were usually discarded as unmarketable. As a consequence, 17.8 percent by weight was discarded. The average size of 170 discarded specimens was 287.2 mm. (11.3 inches). Nevertheless, rex sole were taken in sufficient quantity to remain important in the flatfish catch. They were found in 54 individual drags and made up 24.8 percent of the total catch, averaging 23.4 pounds per drag.

Three species of flatfish were placed in Class III. The curlfin turbot and dover sole were relatively undesirable at Morro Bay. They were taken only rarely, in small amounts, and in small sizes. The markets did not have much use for these fish under these conditions. As a consequence, about 75 percent were discarded. In total, they made up 1.0 percent of the flatfish catch and were represented by 0.9 pounds in an average drag. A third Class III flatfish was the hornyhead turbot, represented by just four specimens in two drags. Of these four, one was discarded and three marketed.

The remaining three kinds of flatfish were considered undesirable and were always discarded at Morro Bay. The most important of these was the Pacific sanddab. The main objection to this fish was its small size, the average for 120 specimens being 211.4 mm. (8.3 inches). They made up 4.3 percent of the flatfish catch at Morro Bay, representing 4.0 pounds in an average drag. By weight, 94.4 percent of the sanddabs were taken in three of the flatfish drags; they showed up only rarely and in small amounts in the rockfish catch.

The slender sole was another very small Class IV fish having no market value. The average size of 21 specimens was 208.3 mm. (8.2 inches). It was found in only 12 drags and made up just 0.3 pounds in an average drag.

Finally, arrowtooth halibut were found in only two drags. These fish have very soft flesh and were rejected by the local markets. It represented only 0.05 pounds in an average drag.

In summary, very desirable flatfish made up 69.6 percent by weight of the flatfish catch and were rarely discarded. Less desirable Class II flatfish, represented by rex sole, made up 24.8 percent of the flatfish catch and 43.3 percent of the discard. Undesirable Class III and IV flatfish made up only 5.6 percent of the catch but constituted 51.5 percent of the discard.

Sport Survey

Flatfish made up only 1.2 percent of the total sport take (Figure 3), averaging 0.2 fish per angler day. The species composition in the sport catch was not determined. The negligible importance of the flatfish in the party boat landings precludes any concern over the lack of more particular data for this group.

LINGCOD

Trawl Survey

It seems advisable to treat lingcod in a separate category rather than classify them with the miscellaneous species. They are very desirable Class I fish that cannot be conveniently discussed in relation to any other group. They made up 2.9 percent by weight of the total trawl catch (Figure 2).

Lingcod were found in 56 of the 64 drags in amounts varying from 3 to 350 pounds, with an average for the 64 drags of 60.8 pounds. Only very small specimens were unmarketable, thus 93.1 percent of those taken were retained and sold.

The average lengths of 181 marketed and 70 discarded specimens were 604.7 mm. (23.8 inches) and 395.2 mm. (15.6 inches), respectively. Although fish of the sizes discarded were not really "small" they were of no value to the markets.

Actually, the 60.8 pounds of lingcod taken in an average drag represented very few fish because of their large individual size. Consequently, the comparatively small numbers taken per drag classify lingcod as strictly incidental in relation to the rest of the catch.

Sportfish Survey

Lingcod are prized sportfish wherever they are caught. They grow to a large size, thus holding a position of esteem for the average angler. Their prestige value often outweighs their importance to the catch as a whole.

At Morro Bay lingcod made up 3.3 percent of all fish caught (Figure 3). Their importance in the weight of the catch was greater; forming an estimated 12 percent. Lingcod contributed 0.4 fish in the average daily catch. Only five species of rockfish contributed to the catch in greater quantities than did lingcod.

Some fishermen go fishing exclusively for lingcod, and use large hooks and live bait. Although lingcod do not receive the publicity in the Morro Bay area that they do in the Monterey area, the total catch and catch-per-angler were nearly identical at these two ports in 1957. At Morro Bay, however, lingcod made up a smaller portion of the total catch.

SHARKS AND RAYS

Trawl Survey

Sharks and rays as a group were a poor second to rockfish in total pounds landed. They totaled 188.9 pounds in an average drag compared to 1,731.3 pounds contributed by rockfish. Sharks and rays made

up 8.9 percent by weight of the total trawl catch (Figure 2). During this study five species of sharks, six of skates, and one chimaera (ratfish) were taken (Table 5).

TABLE 5

Species of Sharks and Rays Taken in 64 Drags Off Morro Bay—August, 1957 to July, 1958

Species	Caught			Discarded			Number of occurrences (drags)	Desirability
	Total pounds	Percent of total sharks and rays	Average pounds per haul	Total pounds	Percent of species total	Average pounds per haul		
Ratfish	5,242	43.4	81.9	5,242	100.0	81.9	56	IV
Dogfish	4,125	34.1	64.5	4,125	100.0	64.5	45	IV
Longnose skate	1,303	11.6	21.8	1,383	99.3	21.6	49	IV
Soupfin	622	5.1	9.7	5	0.8	0.1	11	I
Big skate	312	2.6	4.9	312	100.0	4.9	10	IV
Electric ray	152	1.2	2.4	152	100.0	2.4	20	IV
California skate	87	0.7	1.4	87	100.0	1.4	3	IV
Blue shark	60	0.5	0.9	60	100.0	0.9	1	IV
Sandpaper skate	41	0.3	0.6	41	100.0	0.6	15	IV
Filetail shark	24	0.2	0.4	24	100.0	0.4	1	IV
Monterey skate	20	0.2	0.3	20	100.0	0.3	9	IV
Sixgill cowshark	7	0.1	0.1	7	100.0	0.1	1	IV
Total	12,085	100.0	188.9	179.1	94.8	179.1		

Only one of these was used commercially at Morro Bay, the remaining 11 were discarded. The discard of 94.8 percent of the sharks and rays was a large part of the unsaved poundage of an average drag, amounting to 179.1 (72 percent) of the 248.5 pounds discarded.

Just two classes were represented in the shark and ray catch: the very desirable Class I and the very undesirable Class IV. A Class I shark accounted for 98.0 percent of the marketed and 0.1 percent of the discarded catch, while Class IV sharks and rays made up 2.0 percent of the marketed and 99.9 percent of the discarded catch.

The only desirable shark was the soupfin, which accounted for 5.1 percent of the total weight of sharks and rays caught. They were taken in 11 of the 64 drags. Soupfin are valued both for their liver (a source of vitamin A) and for their flesh. They are not taken efficiently by trawl gear since they can usually escape capture. Fishermen feel that a soupfin in the net generally indicates an abundance of them in the area.

The other 11 species of sharks and rays caught were all considered undesirable. Three of these, the dogfish, ratfish, and longnose skate, made up 89.1 percent of the sharks and rays caught. These three were caught with regularity and were a nuisance to fishermen, who sorted them out of their catch and discarded them. An average of 168.2 pounds of these three was taken per drag.

Much of the dogfish was taken in a single flatfish drag off of Point Sal. They made up over 75 percent of this drag, amounting to 2,810 pounds, and represented 68 percent of the dogfish taken in all drags.

Once during the study, a small amount of longnose skate was marketed. As a result, a small amount of Class IV fish appeared in the marketed portion. The remaining eight species of sharks and rays were caught relatively infrequently and constituted 5.8 percent of the discarded category.

Sportfish Survey

Sharks and rays are rarely brought ashore by the sport fishermen, consequently no assessment of their importance could be made from the sampling. Conversation with party boat operators and fishermen indicated they were rarely taken. Party boat anglers used hooks and bait that were too small to interest sharks and rays; as a consequence few were caught. Their importance to the catch therefore was negligible.

MISCELLANEOUS

Trawl Survey

Fourteen species did not fall into any of the previous categories and were not important enough to be placed in separate groups. Six of these were taken in very limited amounts (Table 6). This miscellaneous group made up in weight only 1.5 percent of the trawl catch (Figure 2), and contributed 31.5 pounds in an average drag.

This category contained no Class I or very desirable fish, and only one Class II and two Class III species. The remaining 10 species were worthless Class IV fish. The lack of valuable fish in this group resulted in a discard of 79.4 percent of them.

TABLE 6

Species of Miscellaneous Fishes and Mollusks Taken in 64 Drags Off Morro Bay August, 1957 to July, 1958

Species	Caught			Discarded			Number of occurrences (drags)	Desirability
	Total pounds	Percent of total miscellaneous	Average pounds per haul	Total pounds	Percent of species total	Average pounds per haul		
Sablefish	803	39.9	12.6	689	85.7	10.8	48	III
Octopus	313	15.6	4.9	26	8.5	0.4	10	II
Threadfin sculpin	243	12.1	3.8	243	100.0	3.8	42	IV
Pacific hake	218	10.8	3.4	218	100.0	3.4	20	IV
Jack mackerel	215	10.7	3.4	202	94.0	3.2	6	III
Northern midshipman	176	8.7	2.7	176	100.0	2.7	11	IV
Pink seaperch	20	0.9	0.3	20	100.0	0.3	4	IV
Shortspined combfish	19	0.9	0.3	19	100.0	0.3	4	IV
Cottid	4	0.2	0.1	4	100.0	0.1	2	IV
Convictfish	1	0.1	–	1	100.0	–	1	IV
Spotted cusk-eel	1	0.1	–	1	100.0	–	3	IV
Eelpout	–	–	–	–	100.0	–	2	IV
California pompano	–	–	–	–	100.0	–	1	IV
Poacher	–	–	–	–	100.0	–	2	IV
Total	2,013	100.0	31.5	1,599	79.4	25.0		

The marketed portion was made up of 69.2 percent Class II and 30.8 percent Class III species. The discard contained 1.6 percent Class II species, and almost equal portions of Class III and IV fish.

The desirable Class II species was the octopus, *Paroctopus apollyon*. This species contributed 15.6 percent of the miscellaneous category, or 4.9 pounds in the average drag. Octopuses were taken in 10 of the 64 drags. Octopuses were generally not discarded as they brought a good price in the markets. The one case in which one was discarded was the first day of a two-day trip where the single specimen would not have kept until the vessel returned to port.

Sablefish were the most important single species in the miscellaneous category, making up 39.9 percent of the total. Sablefish are placed in Class III since they are usually discarded at Morro Bay. The small amount caught (12.4 pounds per drag) and the small average size (459.6 mm. or 18.1 inches) combined to make them unmarketable at Morro Bay. As a consequence, 85.7 percent was discarded. Most of the remaining 14.3 percent was salted on the boats for the use of the crew.

The other Class III fish, jack mackerel, made up 10.7 percent of the miscellaneous category with 3.4 pounds in an average drag. They were recorded only during June and July, 1958, appearing in six of the 15 drags checked during these months. Although jack mackerel were valuable in quantity, the small amounts were usually discarded. A few fish were occasionally kept by the crew or given away on the docks. The lack of a market for this fish resulted in a discard of 93.3 percent.

The remaining miscellaneous were undesirable Class IV fish. Eleven kinds made up this group; three occurred in some quantity. These three, the threadfin sculpin, Pacific hake, and northern midshipman, were completely discarded, being of no value to the markets or fishermen. These three made up 31.6 percent of the miscellaneous category.

The remaining 2.2 percent of the category consisted of eight species which showed up only rarely and in small amounts.

Sportfish Survey

Eight species identified in the party boat catches cannot be placed into any of the groups discussed previously. These were taken incidentally while fishing for the more common kinds. In addition, a few fish that could not be identified have been included in this category (Table 3).

As a group, the miscellaneous fishes made up 2.1 percent of the catch (Figure 3). Because some of these were of a large size, the category takes on somewhat more importance when expressed in weight, an estimated 4 percent. About 0.3 fish in this category went into an average angler's daily catch.

Three species made up 85 percent of the numbers taken. These three were jack mackerel, greenling seatrout, and cabezon. Jack mackerel were the most important, being very popular with the sport fishermen because of their fighting ability. They were usually taken while jigging for blue rockfish in inshore areas. The cabezon is especially good eating and its large size makes it a favored species. Greenling seatrout are also well liked for their tastiness. Alhough these three are popular with sportsmen, they were taken in quite small quantities at Morro Bay.

King salmon and white seabass made up 10 percent of the miscellaneous catch. They were much desired and some fishermen went only in quest of them. Often a "salmon" party boat would start the day trolling for salmon but if fishing was poor it would switch to bottomfishing later in the day. Thus, the importance of salmon and white seabass is greater than the number caught would indicate, since many hours were spent in unsuccessful pursuit of them. Catches of these two totaled only 0.03 fish per angler day during this study.

The remaining three identified species and the fish that could not be identified rarely were taken and did not contribute significantly to the catch. They were not normally taken in the areas fished or with the gear used.

DISCUSSION OF THE CATCHES

Trawl Survey

Characteristics of the Catch

The preceding discussions were presented to give separate consideration to discards, desirability classes, and categories. Let us now look at the catch as a whole to tie these various classifications together.

First, the trawl catch was composed of, by weight, 82.2 percent rockfish, 4.5 percent flatfish, 2.9 percent lingcod, 8.9 percent sharks and rays, and 1.5 percent miscellaneous fishes (Figure 2). The composition of each of these categories was discussed earlier in terms of desirability classes and discard.

Class I fish made up 87.6 percent of the weight caught. Fifteen species have been placed in this class, 10 of which are rockfish. Two Class II species, made up 1.3 percent, and six Class III fish, comprised 1.0 percent of the catch. Class IV fish made up the remaining 10.1 percent. This latter class is represented by 29 species, 22 of which are sharks, rays, and miscellaneous species. Class I discard amounted to 0.8 percent; Class II, 16.3 percent; Class III, 84.1 percent; and Class IV, 99.9 percent (Figure 4). The large size and low discard of Class I fish combined with the fair size and high discard of the Class IV fish to result in a discard for the total catch of 11.8 percent (Figure 4). It is apparent that Class I were dominant in the market part and Class IV in the discard part of the catch.

By categories, rockfish were dominant in the marketed portion of the catch; they comprised 91.5 percent. The remaining 8.5 percent of marketed fish was a combination of 4.6 percent flatfish, 3.0 percent lingcod, 0.5 percent sharks and rays, and 0.4 percent miscellaneous species (Figure 5).

Sharks and rays made up 72.1 percent of the discard. The rest of the discard was 12.3 percent rockfish, 10.0 percent miscellaneous species, 3.9 percent flatfish and 1.7 percent lingcod (Figure 5). The percentages for the discard combine all classes in each category; it must be remembered that parts of each category belong to lower classes and were considered worthless. Thus, two-thirds of the rockfish in the discard were Class III and Class IV species which have little value. The percentage of flatfish and lingcod in the discard was small, partly because of the small amounts they contributed, but also because comparatively few of them were discarded.

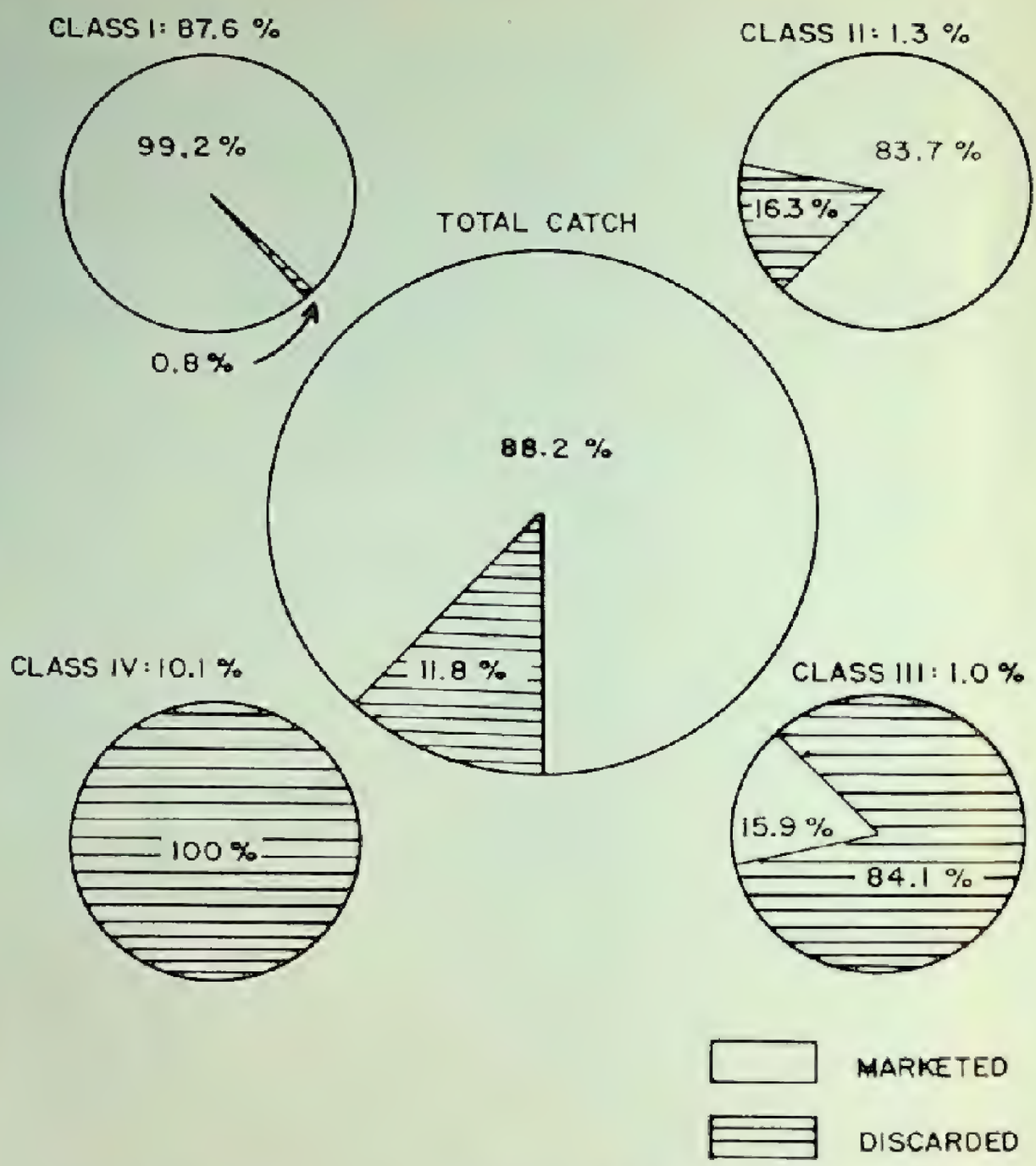

FIGURE 4. Discard of trawlers at Morro Bay. Percentages are based on weight.

Sportfish Survey

The party boat catch was much less complicated since discard and desirability were not a problem. By numbers the catch was composed of, 93.4 percent rockfish, 1.2 percent flatfish, 3.3 percent lingcod, and 2.1 percent miscellaneous fishes (Figure 3). Thirty-one species were recorded.

Species Composition of the Catch

Trawl Survey

Although 52 species were present in the trawl catch, most were of minor importance.

Considering only those species that individually contributed more than 1 percent by weight of the marketable trawl fish, we have just

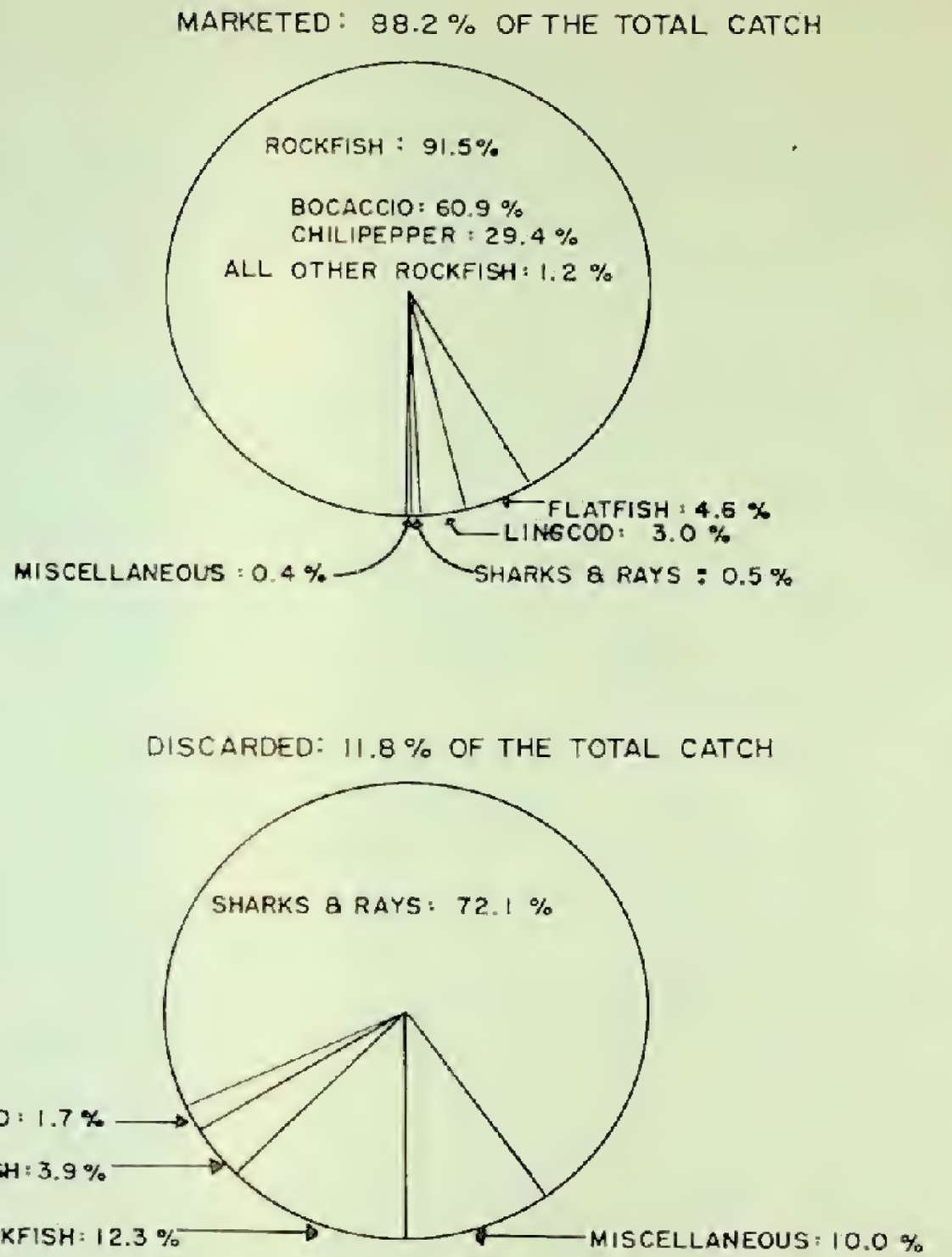
MARKETED: 88.2 % OF THE TOTAL CATCH
ROCKFISH : 91.5%
BOCACCIO: 60.9 %
CHILIPEPPER : 29.4 %
ALL OTHER ROCKFISH: 1.2 %
FLATFISH : 4.6 %
LINGCOD: 3.0 %
MISCELLANEOUS : 0.4 %
SHARKS & RAYS : 0.5 %
DISCARDED: 11.8 % OF THE TOTAL CATCH
SHARKS & RAYS: 72.1 %
LINGCOD : 1.7 %
FLATFISH: 3.9 %
ROCKFISH: 12.3 %
MISCELLANEOUS: 10.0 %

FIGURE 5. Composition of marketed and discarded portions of the Morro Bay trawl catch Percentages are based on weight.

five species. Foremost among these were the bocaccio and chilipepper which together made up 90.3 percent. Rex and petrale sole added another 3.9 percent and lingcod contributed 3.1 percent. Nineteen other species made up the remaining 2.7 percent of the marketed catch.

The discard portion of the catch contained a greater number of species, 44 having been present. Of these, five contributed more than 2.5 percent each by weight. Three species of sharks and rays (dogfish, longnose skate, and ratfish) made up 67.6 percent of the discard, stripetail rockfish contributed 4.7 percent, and sablefish 4.3 percent. These five species thus accounted for 76.6 percent of the total discard.

This still leaves 23.4 percent of the discard and 39 species to be accounted for. These may be divided into two groups, one of species having added individually from 1.0 to 2.5 percent by weight to the discard, the other of species having added less than 1.0 percent each. The 12 species in the first group contributed 19.7 percent of the discard. They are bocaccio, chilipepper, greenstriped rockfish, shortbelly rockfish, rex sole, sanddab, lingcod, big skate, hake, threadfin sculpin, midshipman and jack mackerel. The remaining 27 species contributed 3.6 percent of the total discard.

Sportfish Survey

Of the 30 species identified in the sport catch, only 10 (nine rockfish and the lingcod) contributed more than 2.0 percent individually to the total. Foremost of these were blue and olive rockfish which produced 50 and 15 percent, respectively. The eight other species in order of importance were yellowtail rockfish, vermilion rockfish, bocaccio, lingcod, canary rockfish, whitebelly rockfish, gopher rockfish, and widow rockfish. These eight contributed 27 percent of the catch. Rosy rockfish, greenspotted rockfish, starry rockfish and jack mackerel each accounted for approximately 1 percent. Finally, 2 percent was produced by the remaining 16 identifiable species and 2 percent by unidentified rockfish, flatfish, and miscellaneous.

INTERFISHERY COMPETITION

The question of competition between these two fisheries has arisen often. It is well to take a moment here to consider possible competition in the light of this report.

Commercial trawlers are prevented by law from operating closer than three miles to shore. This effectively limits the trawlers to depths exceeding 50 fathoms (300 feet) in most of their fishing area. In addition, the trawlers must operate on a snag-free bottom, with the result that much potential area beyond the three-mile limit must be avoided.

These restrictions result in an effective separation between the two fisheries. Hook and line fishermen can fish in any depth and on any bottom. Their most productive areas are in shallow water close to shore where trawl fishing is prohibited.

Perhaps more important, the two fisheries depend on different kinds of fish. A comparison of catches shows that the same species are taken by the two fisheries only to a minor degree (Figure 6). The commercial fishermen depend on deep water forms, such as the bocaccio and chilipepper while the party boats primarily pursue shallow water forms such as the blue, olive, and yellowtail rockfish.

To be sure, some overlap does exist; however, in almost every case where this occurs, the species in question makes up a much greater part of one fishery than the other. The amounts taken by the second fishery are insufficient to place a drain on the species. An exception is the lingcod, which forms 3 percent of the catch of each fishery. Here the wide range of the species and the separation of the fisheries imposed by the three-mile limit, insure that neither will be able to deplete the stocks fished by the other.

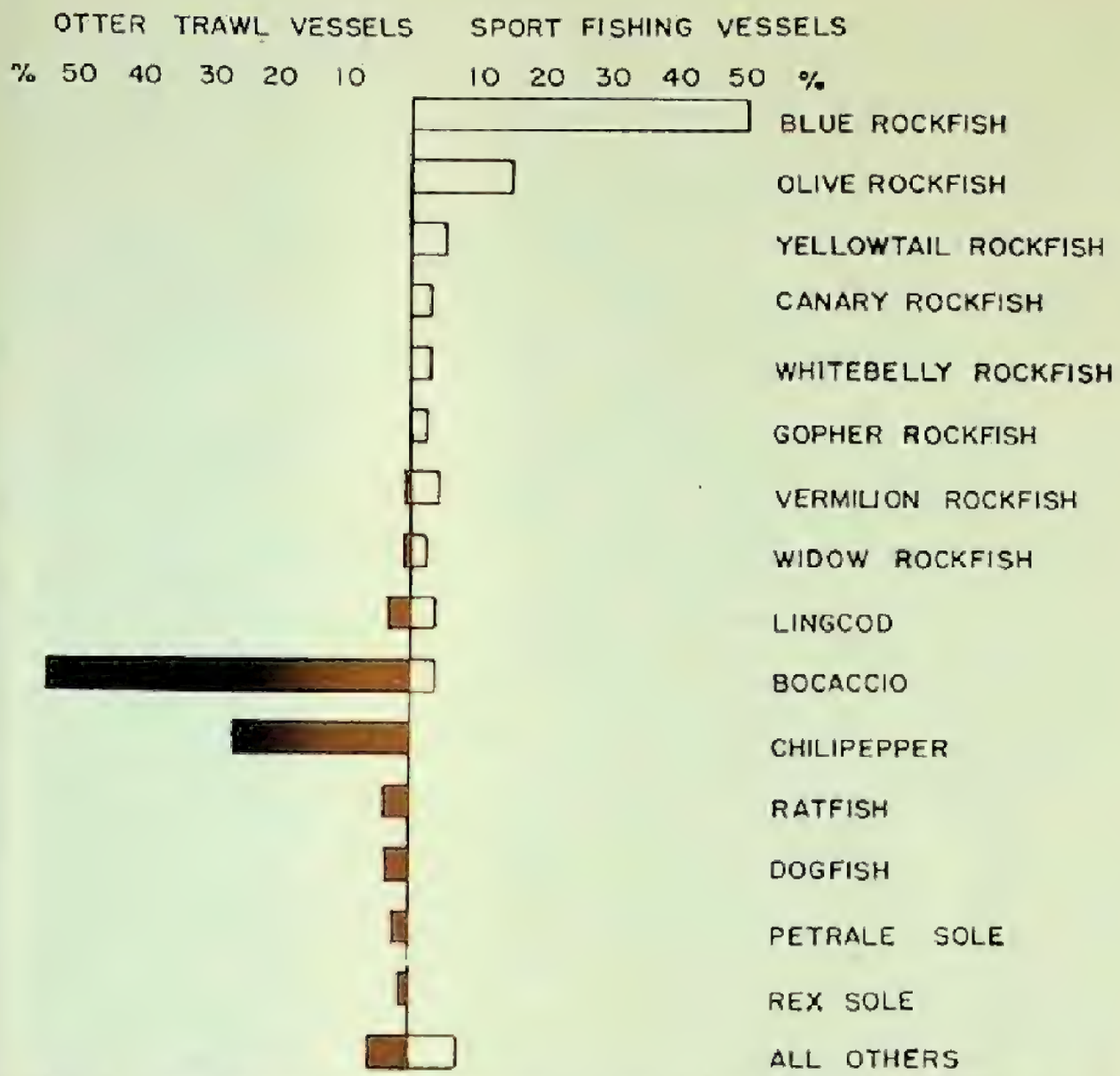

FIGURE 6. Comparison of species composition of trawl and sportfish catches. Percentages are based on number landed by party boats and weight landed by trawlers.

In fisheries where different species are taken and different areas are fished, no serious competition can exist.

ACKNOWLEDGMENTS

We wish to extend our thanks for the co-operation afforded us by all phases of the fishing interests at Morro Bay. The commercial fishermen welcomed us aboard their vessels and endured our sampling; various plants made both space and fish available for our inspection; and party boat operators allowed us to sample catches made aboard their vessels. Without this generous co-operation, this survey would not have been possible.

Many department employees took part in the sampling work. Doyle E. Gates initiated the program for the trawl survey and laid the ground work for carrying it through. Julius B. Phillips contributed a good deal of time and effort to carrying out the sampling, as well as in training personnel in the identification of the various species taken. Much of the actual sampling for the trawl survey was done by George

Isaacs and Leonard Perkins. Robert Menchen and Donovan Johnson carried out the major portion of the sport fish sampling. Considerable editorial assistance for this report was received from John E. Fitch, Harold G. Orcutt, and Edgar A. Best. To all who aided this survey in any way, we extend our sincere thanks.

SUMMARY

The otter trawl and party boat fisheries have grown considerably in the last few years. This growth caused concern over possible competition for certain species of fish and resulted in a survey of the two fisheries.

The objectives of this survey were to determine the composition of the catches of both fisheries. In addition, the amount of discard and the sizes of fish taken by the trawlers were to be assessed. These objectives were attained by sampling the trawl catch at sea as well as in the markets, and by sampling the party boats as they returned to port.

The major effort of the trawl fleet was expended in the deeper waters (300 to 750 feet) in the areas adjacent to Morro Bay although market demands resulted in trips for other species to more distant locations. Five trawl vessels were operating from Morro Bay. Twenty-four trips, comprising 64 individual drags, were made aboard these vessels.

The party boat fleet operated inshore from the trawl fleet in depths of 30 to 300 feet. Twenty-six party boats operated in the Morro Bay area. In the course of this survey 890 anglers' catches were examined.

Fifty-two species were taken by the trawlers while 31 were identified in the party boat catch. These were grouped into five categories: rockfish, flatfish, lingcod, sharks and rays, and miscellaneous fishes. In addition, trawl caught fish were further broken down by desirability into four classes.

By weight the trawl catch was composed of 82.2 percent rockfish, 4.5 percent flatfish, 2.9 percent lingcod, 8.9 percent sharks and rays, and 1.5 percent miscellaneous fishes. An average drag contained 2,106.9 pounds of fish of which 248.5 pounds or 11.8 percent, were discarded.

By numbers the party boat catch was composed of 93.4 percent rockfish, 1.2 percent flatfish, 3.3 percent lingcod, and 2.1 percent miscellaneous fishes. The average catch per angler was 13.9 fish.

The trawl catch was dominated by bocaccio and chilipepper, which made up 80.0 percent of the weight caught. Other species contributing significantly were ratfish, 3.9 percent; dogfish, 3.1 percent; lingcod, 2.9 percent; petrale sole, 2.6 percent; rex sole, 1.1 percent; and longnose skate, 1.0 percent.

The dominant species in the party boat catch were blue and olive rockfish, making up 65.4 percent of the numbers caught. Other important species were yellowtail rockfish, 5.3 percent; vermilion rockfish, 4.6 percent; bocaccio, 3.8 percent; lingcod, 3.3 percent; canary rockfish, 3.0 percent; whitebelly rockfish, 2.9 percent; gopher rockfish, 2.3 percent; and widow rockfish, 2.1 percent.

Because of the separation of areas fished and the differences in species taken, no interfishery competition exists between the two fisheries at Morro Bay.

CATCH RECORDS FOR SEVENTEEN SHARK DERBIES HELD AT ELKHORN SLOUGH, MONTEREY BAY, CALIFORNIA[1]

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The recent increases in the incidence of shark attack in many parts of the world including California make it evident that a great deal more information is needed about these voracious scavengers of the sea. Of the 32 species of sharks known from California, at least a dozen are potentially dangerous to the swimmer and skindiver. Only the man-eater (*Carcharodon carcharius*) is usually considered capable of immediate and unprovoked attack.

Since the nebulous difference that determines whether a given shark or ray is friendly or dangerous can be quickly changed by a great variety of fluctuating environmental factors, it becomes essential to learn everything possible about all elasmobranchs in this region.

The sports fisherman can usually draw upon a goodly amount of information dealing with the ecology, food habits, growth rates, reproductive potential, sex ratios and distribution of the species he catches, but this same kind of information is almost entirely lacking for the majority of California sharks and rays. Only two species have been studied in any detail, the soupfin (*Galeorhinus zyopterus*) and the dogfish (*Squalus sucklegi*). In these cases the studies were made possible because of the great wartime value of the livers as a source of vitamin A as well as oil. Although the other California sharks and rays have had only a negligible commercial value, they do represent a vast untapped protein resource that can always be made available. This report, then, presents some of the kinds of information urgently needed about California's elasmobranch population.

Elkhorn Slough is located on the east side of Monterey Bay about halfway between Santa Cruz and Monterey. Originally it was a part of the Salinas river system and served as its outlet until about 1908. Since that time this shallow lagoon has received little fresh water so that its salinity is fairly close to that of Monterey Bay. Usually the temperature is not more than one or two degrees above that of the outside water (MacGinite, 1935, p. 645). Fluctuations in yearly abundance of sharks and bat rays in the slough could not be correlated with the differences in average weekly temperatures as recorded at the Moss Landing plant of the Pacific Gas and Electric Company.

Some years ago two sports clubs in the Monterey Bay area, the Castroville Rod and Gun Club and the Pajarro Valley Rod and Gun Club, began their sponsorship of shark derbies in Elkhorn Slough.

[1] Submitted for publication September, 1959.

TABLE 1

Catches of Seventeen Shark Derbies by Species and Numbers, Elkhorn Slough, Monterey Bay, California, 1951 to 1959

SPECIES	Year, Month and Day																Total
	1951	1952		1953		1954		1955		1956		1957		1958		1959		
	May 20	June 8	July 27	June 14	June 28	June 6	June 20	June 5	June 19	June 10	June 24	June 16	July 14	June 1	June 15	June 7	June 21	
Bat Ray	**29**	**59**	**39**	**141**	**49**	**64**	**53**	**64**	**59**	**102**	**48**	**65**	**68**	**58**	**54**	**66**	**53**	**1,071**
Males	8	27	21	69	15	25	20	16	24	41	10	23	30	20	16	22	24	411
Females	21	32	18	72	34	39	33	48	35	61	38	42	38	38	38	44	29	660
Shovelnose guitarfish	**18**	**15**	**49**	**76**	**48**	**56**	**68**	**21**	**43**	**50**	**41**	**44**	**22**	**11**	**2**	**45**	**27**	**636**
Males	4	3	18	26	13	11	26	8	18	12	22	20	9	3	1	15	10	219
Females	14	12	31	50	35	45	42	13	25	38	19	24	13	8	1	30	17	417
Leopard shark	**14**	**32**	**16**	**26**	**6**	**32**	**44**	**19**	**16**	**25**	**18**	**39**	**29**	**55**	**37**	**72**	**66**	**546**
Males	7	15	9	11	5	18	22	5	10	20	13	20	15	33	17	36	30	286
Females	7	17	7	15	1	14	22	14	6	5	5	19	14	22	20	36	36	260
Round stingray		**1**	**1**		**1**	**1**			**1**	**1**					**2**	**1**	**1**	**10**
Gray smoothhound			**1**									**1**			**1**	**2**		**5**
Brown smoothhound																	**3**	**3**
Thornback		**1**							**1**									**2**
Total catch	**61**	**108**	**106**	**243**	**104**	**153**	**165**	**104**	**120**	**178**	**107**	**149**	**119**	**124**	**96**	**186**	**150**	**2,273**
Total weight in pounds		1,800	1,217	3,483	2,043	2,488	2,136	2,359	1,579	3,837	2,770	2,228	1,784	1,935	1,604	2,498	2,148	

Two derbies are held each year, usually in June, but occasionally in July or May. Preliminary data on the early catches were presented by Herald and Dempster (1952) and Herald (1953). Some of that information is also incorporated in Table 1 which gives the catch records for 17 of the 18 derbies that have been held (the 1950 derby was missed). The total number of elasmobranchs examined comes to 2,273. This included 1,071 bat rays (*Myliobatis californicus*), 636 shovelnose guitarfish (*Rhinobatos productus*), 546 leopard sharks (*Triakis semifasciata*), 10 round stingrays (*Urolophus halleri*), 5 gray smoothhounds (*Mustelus californicus*), 3 brown smoothhounds (*Rhinotriacis henlei*) and 2 thornbacks (*Platyrhinoidis triseriata*).

All of the derbies were operated in the same manner. Fishing began at 7 a.m. and ended precisely at 1 p.m. Each derby participant was charged a fee, usually $1.50. Prizes of fishing and hunting equipment were awarded to the persons making the largest catches, and profits resulting from the derbies have been used in the youth programs of the individual clubs.

Although a greater number of fishermen will increase the catch to a certain extent, we believe that the yield at the derbies is more accurately a reflection of the number of elasmobranchs in the slough on that particular day.

Each year the fishermen have caught a few bony fishes in the slough incidental to the elasmobranch fishing. Striped bass (*Roccus saxatilis*) up to 30 pounds were caught during five derbies. Jacksmelt (*Atherinopsis californiensis*) often have been taken, and the omnipresent staghorn sculpin (*Leptocottus a. armatus*) was always ready to steal the bait. Four species have been represented by a single specimen during the 17 derbies: California halibut (*Paralichthys californicus*) 23 pounds; starry flounder (*Platichthys stellatus*) about 10 inches (254 mm.) SL., sarcastic fringehead (*Neoclinus uninotatus*) 6½ inches (165 mm.) SL.; and a spotted snake eel (*Ophichthus triserialis*) 33⅛ inches (842 mm.), two pounds. At times the sea hare (*Aplysia californica*) has been rather abundant in the slough. Derby fishermen often brought this snail in and were usually mystified about its identification. All rare fishes taken at the derbies have been deposited in the collections of the Department of Ichthyology of the California Academy of Sciences.

As a part of his longtime study of the ecology of the invertebrate fauna of Elkhorn Slough, MacGinite (1935) dealt with 10 species of fishes occurring in the lagoon. The bat ray was the only elasmobranch studied.

BAT RAY (*Myliobatis californicus*)

The total catch of bat rays at any one derby (Table 1) has ranged from 29 (May 20, 1951) to 141 (June 14, 1953). The largest fishes caught at the shark derbies always have been female bat rays, and the largest recorded at Elkhorn Slough weighed 142 pounds (Table 2). The accepted maximum weight for this species usually has been given as 150 pounds. However, recently a giant female of 209 pounds was captured in Newport Bay (March 31, 1958) by members of the Redondo Rod and Gun Club, an organization that specializes in the catch-

TABLE 2

Weights of 1,003 Bat Rays Caught in Elkhorn Slough, Monterey Bay, California at Sixteen Shark Derbies Held During June and July From 1952 Through 1959

Range in weight (pounds)	Males	Females	Total
0– 2	28	39	67
3– 7	121	115	236
8– 12	99	77	176
13– 17	84	76	160
18– 22	41	50	91
23– 27	7	37	44
28– 32	1	31	32
33– 37	1	26	27
38– 42	0	30	30
43– 47	0	23	23
48– 52	0	20	20
53– 57	0	17	17
58– 62	0	12	12
63– 67	0	13	13
68– 72	0	11	11
73– 77	0	7	7
78– 82	0	7	7
83– 87	0	4	4
88– 92	0	5	5
93– 97	0	6	6
98–102	0	2	2
103–107	0	3	3
108–112	0	4	4
113–117	0	1	1
118–122	0	2	2
123–127	0	0	0
128–132	0	0	0
133–137	0	1	1
138–142	0	2	2
Totals	382	621	1,003

ing and study of bat rays. The actual catch was made by Ralph Cannon, assisted by Don Ethridge, Bob Schwartz and Don Cannon. All of these witnessed the weighing which was carried out on a Hansen spring scale. They have furnished us with signed affidavits regarding the details of the event as well as a certified calibration of the scale. The fish was so large that it had to be cut into three sections for weighing (154-pound center section with 27- and 28-pound "wings"). Therefore, this new record, 59 pounds greater than any previously known, should be accepted as correct.

The average weight for derby-caught Elkhorn Slough females was 25.25 pounds. In this area, a female must weigh at least 50 pounds before she is capable of bearing young. Of the 1,003 bat rays upon which we have data, only 97 females, or about 9.4 percent were capable of reproduction. In June and July many of the large females were carrying near-term embryos. During internal examination, attempts have always been made to remove any living young to the tanks in the adjacent aquarium truck, and to raise them subsequently in the aquarium. Unfortunately, most of these young have remained alive for

only a few days or a few weeks. However, one Caesarian-delivered female of June 15, 1958, did survive and at the end of 13 months had a pectoral width of 14 inches (356 mm.) and a weight of 1 pound, 11 ounces. In one year the growth increase was approximately five-eighths inch (16 mm.) in pectoral width and 5 ounces in weight. It is suspected that a wild individual would grow much faster.

The female bat ray has a paired uterus. Females of 50-60 pounds usually have one or two young in each horn of the uterus whereas females of 130-140 pounds may have 5 or 6 in each horn. Twelve is the largest number of young we have found in any female. The young are always born tail first with the "wings" rolled up over the body.

The difference in size between male and female bat rays is amazing. Although the largest female weighed 142 pounds, the largest male weighed only 37 pounds, and their usual maximum weight has been 22 pounds. Only nine of 382 (2.36 percent) weighed more than 22 pounds (Table 2). We have not found any ripe males at Elkhorn Slough during June and July. However, from the size of the gonads of those caught, it is suspected that the male must weigh at least 10 pounds before becoming sexually mature. The average weight for the 382 males was 8.02 pounds as compared with the 25.25-pound average for 621 females.

The sex ratio for all the bat rays caught in Elkhorn Slough has been 38 males to 62 females, or about 1.6 females for each male. Whether this ratio holds for other sections of the Pacific Coast remains to be determined.

Because of the vast difference in size of male and female bat rays, one of the questions often asked at the derbies has been how to distinguish the sexes. This may be easily done by turning the shark or ray on its back and looking for the claspers which are possessed by all males. These paired appendages are attached just behind the anal opening and are on the inside margins of the paired ventral or pelvic fins. The claspers are conspicuous on male adults but will be difficult to observe on immature fish unless very careful examination is made.

In Elkhorn Slough bat rays fed chiefly upon clams, usually *Schizothaerus nuttalli*, and occasionally peanut worms (sipunculids). They had also fed upon shrimp (*Callianassa* and *Upogebia*), nereid worms, crabs (*Emerita analoga* and *Cancer productus*) and fish (*Clevelandia ios*).

SHOVELNOSE GUITARFISH (*Rhinobatos productus*)

The total catch of shovelnose guitarfish at any one derby ranged from two (June 15, 1958) to 76 (June 14, 1953). Based on 194 males (Table 3) the modal weight was eight pounds and the average 8.96. The largest male weighed 19 pounds but the length measurement was not available. For the 370 females, the weight distribution was bimodal at 19 and 21 pounds with an average of 16.95 pounds. The largest female weighed 29 pounds and measured 52⅝ inches (1,363 mm.).

Although most of the adult females have had eggs and embryos in their ovaries at the time of the derbies, very few young fish have been included in the catches. For the derbies previous to 1959, we had con-

TABLE 3

Weights of 564 Shovelnose Guitarfish and 485 Leopard Sharks Caught in Elkhorn Slough, Monterey Bay, California at Sixteen Shark Derbies Held During June and July From 1952 Through 1959

Weights (pounds)	Shovelnose guitarfish			Leopard sharks		
	Males	Females	Total	Males	Females	Total
1	2	7	9	38	34	72
2	4	4	8	16	15	31
3	1	1	2	11	8	19
4	1	3	4	17	9	26
5	4	4	8	11	8	19
6	9	6	15	13	10	23
7	16	10	26	11	11	22
8	51	5	56	11	10	21
9	39	5	44	14	11	25
10	25	6	31	8	7	15
11	8	8	16	9	17	26
12	11	14	25	13	12	25
13	8	8	16	14	4	18
14	5	20	25	13	12	25
15	5	19	24	9	4	13
16	2	24	26	8	3	11
17	0	28	28	11	3	14
18	1	33	34	11	5	16
19	2	31	33	4	3	7
20	0	28	28	6	6	12
21	0	34	34	4	9	13
22	0	19	19	0	8	8
23	0	18	18	0	5	5
24	0	13	13	0	4	4
25	0	7	7	0	2	2
26	0	4	4	1	6	7
27	0	4	4	0	2	2
28	0	4	4	0	0	0
29	0	3	3	0	1	1
30	0	0	0	0	0	0
31	0	0	0	0	0	0
32	0	0	0	0	0	0
33	0	0	0	0	1	1
34	0	0	0	0	1	1
35	0	0	0	0	1	1
Totals	194	370	564	253	232	485

cluded that the young were seldom born in the Monterey area. This was well demonstrated by the fact that only seven of 536 taken in the 15 derbies through 1958 weighed three pounds or less. By contrast, the two 1959 derbies produced 12 juveniles in this weight range. We suspect that the warmer currents along the California coastline during 1959 have been partly responsible for this change. In the La Jolla area there are often many small *Rhinobatos* weighing two pounds or less during the months of June and July. Limbaugh (1955) reported guitarfish were absent during the winter in the eight Southern California areas in which he made underwater observations. He also reported a male guitarfish that attempted to remove a portion of the calf

from the leg of a skin diver collecting sand dollars in 18 feet of water.

The most striking feature of the guitarfish data (Tables 1 and 3) is the atypical sex ratio. For every male there were about two females, a ratio of 34 to 66 (194 males and 370 females). This may indicate that the sexes are segregated during a portion of the year, as had been demonstrated for the soupfin *(Galeorhinus zyopterus)* and for some Atlantic sharks.

Stomach contents showed that the preferred food was mostly small crabs. Occasionally small fishes such as the goby, *Clevelandia ios*, were found in the stomachs. In the aquarium guitarfish feed readily on any kind of chopped fish, and survive for as long as 8 to 10 years without difficulty.

LEOPARD SHARK (*Triakis semifasciata*)

The total catch of leopard sharks at any one derby (Table 1) has ranged from six (June 28, 1953) to 72 (June 7, 1959). The largest female weighed 35 pounds and the largest male 26 (Table 3). The lengths of these were 57½ and 52⅝ inches, respectively (1,460 and 1,342 mm.). The 26-pound weight for the male may represent an error since none of the other 252 males weighed over 21 pounds. By comparison, the largest male leopard shark of many hundreds caught in San Francisco Bay weighed 18 pounds. Average weight for the Elkhorn Slough male leopard sharks was 8.88 pounds and for the females 10.75. The sex ratio of Elkhorn Slough male and female leopard sharks was a fairly normal 52:48 (253 males and 232 females).

Although many of the small individuals were not more than a few weeks old, none of the adult females contained near-term embryos. However, many of these adult females did have conspicuous eggs in the ovaries.

Stomach contents indicated that in Elkhorn Slough the preferred diet included crabs, clams and fish, especially the midshipman *(Porichthys notatus)* when available.

ROUND STINGRAY (*Urolophus halleri*)

Ten round stingrays were caught at the derbies. Their presence in the catches was somewhat erratic (Table 1). Surprisingly enough, eight of the ten were males, and for the remaining two, the sex had unfortunately not been recorded. Although the sample is small, and distributed over seven years, it does suggest the possibility that a sex segregation may exist for this species.

The weights for the round stingrays ranged between 1.5 and 2.0 pounds. Internal examinations were not made. It should be noted that Elkhorn Slough is the northernmost extent of the range for the round stingray.

GRAY SMOOTHHOUND (*Mustelus californicus*)

Three of the five gray smoothhounds were very small males: 15 inches (380 mm.), 2 ounces, July 27, 1952; 13 inches (327 mm.), 3 ounces, June 15, 1958; and 13⅓ inches (340 mm.), 3 ounces, June 7, 1959. This last specimen was an albino, and the first one known for the species. Unfortunately the eye color could not be determined. The two females measured 12¼ inches (320 mm.), June 7, 1959; and 43¼

inches (1,098 mm.), 9¾ pounds, June 16, 1957. The stomach of the large adult contained 10 yellow shore crabs *(Hemigrapsus oregonensis)*. There were 12 ova, six in each ovary. Diameters of the ova averaged approximately three-quarters of an inch (20 mm.). These five specimens represent the present northernmost range for the gray smoothhound, despite the fact that the species was first described from San Francisco Bay nearly 100 years ago. There is reason to suspect that the type may have been collected in Southern California rather than in San Francisco Bay. The present location of the type is unknown.

BROWN SMOOTHHOUND (*Rhinotriacis henlei*)

One of the most puzzling problems about the derbies has been the absence of brown smoothhounds, or at least that was the case until June 21, 1959, when the species was caught for the first time. Its rarity in Elkhorn Slough is difficult to explain since it is the predominant shark in San Francisco Bay. For example, of the 7,211 sharks and bat rays caught at the Coyote Point Shark Derbies held off San Mateo between 1948 and 1954, 3,076 or 42.5 percent were brown smoothhounds.

The three brown smoothhounds caught at the seventeenth Elkhorn Slough Shark Derbies included a very young male weighing four ounces, and two adult females, weighing two pounds and seven ounces, and two pounds, 14 ounces, 33½ inches (852 mm.). This last female was gravid and contained six young (195-197 mm.) that were returned to the aquarium alive.

THORNBACK (*Platyrhinoidis triseriata*)

Only two thornbacks were taken during the 17 derbies. Strangely enough, they were both the same sex, weight and length: females, 5¾ pounds and 29½ inches (750 mm.). Elkhorn Slough is the northernmost extent of the range of this southern species.

SUMMARY

Data are presented on the 2,273 elasmobranch fishes caught at the 17 shark derbies held at Elkhorn Slough, Monterey Bay, California (1951-1959). In order of abundance there were 1,071 bat rays (*Myliobatis californicus*), 636 shovelnose guitarfish (*Rhinobatos productus*), 546 leopard sharks (*Triakis semifasciata*), 10 round stingrays (*Urolophus halleri*), 5 gray smoothhounds (*Mustelus californicus*), 3 brown smoothhounds (*Rhinotriacis henlei*) and 2 thornbacks (*Platyrhinoidis triseriata*). Elkhorn Slough was indicated as the northernmost extent of range for the round stingray, gray smoothhound and thornback.

A new record weight of 209 pounds was recognized for the bat ray. Females of this species weighed 50 pounds before achieving sexual maturity, whereas the males rarely weighed more than 27 pounds, and are probably matured at 10 pounds.

The shovelnose guitarfish had an atypical sex ratio with almost two females for every male. The largest male weighed 19 pounds and the largest female 29.

Male leopard sharks usually did not weigh more than 21 pounds and the maximum for females was 35.

ACKNOWLEDGMENTS

We are greatly indebted to the following for assistance in procuring data at the various shark derbies: Ed Best, Van E. Bozarth, Ruel Crocker, Robert and Lillian Dempster, Robert Hestorff, Ed Kirschbaum, Robert Pepi, Albert Razum, Sam Riskin, Rudy Rusk and Sandro Sandri. We also wish to make special acknowledgment of much helpful assistance from the officers and members of the two clubs involved. The Pacific Gas and Electric Company has furnished us with detailed temperature data on the Elkhorn Slough waters. Valued editorial suggestions were kindly provided by Carol Ferrel and John Fitch. Typing and much of the data preparation were painstakingly carried out by Mrs. Phyllis Corbin.

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OBSERVATIONS ON THE FOOD HABITS OF LONGLINE CAUGHT BIGEYE AND YELLOWFIN TUNA FROM THE TROPICAL EASTERN PACIFIC 1955-1956[1]

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INTRODUCTION

The existence of large deep-living tunas in the tropical eastern Pacific was first demonstrated during operation *Longline*[2] by investigators aboard the California Department of Fish and Game research vessel *N. B. Scofield* in 1953 (Wilson and Shimada, 1955). These large, old fish represent a commercially untouched spawning reservoir and knowledge pertaining to their abundance and distribution is important to a thorough understanding of the eastern Pacific tuna stocks upon which our California tuna industry depends. Therefore, additional exploratory longline fishing and oceanographic cruises were made in 1955 and 1956. The first, in conjunction with expedition *Eastropic*,[3] was designed for studying tuna catches in relation to oceanographic conditions. The second was designed for similar purposes but at a different time of the year (Mais and Jow, ms.).

Because of the importance of food as an environmental factor in the abundance and distribution of fish, tuna stomachs were collected from as many fishing stations as practicable. This report describes the results of an examination of stomach contents from some of the bigeye tuna (*Parathunnus sibi*) and yellowfin tuna (*Neothunnus macropterus*) caught by the longlines.

MATERIALS AND METHODS

Yellowfin stomachs, except for three from the vicinity of Clipperton Island, came from fish captured off Costa Rica while stomachs from bigeye were taken near the equator (Figure 1). Both species were caught on longline gear fishing between 180 and 420 feet beneath the surface. The yellowfin were 72 to 155 cm. fork length, and the bigeye 83 to 184 cm. (Figure 2).

Stomachs were removed from the day's catch immediately after retrieving the gear. A card bearing the species name, fork length in mm., name of collector, and station number was placed inside each stomach, and rubber bands were looped over the cut ends to prevent the con-

[1] Submitted for publication August, 1959.
[2] An exploratory fishing and oceanographic cruise to the eastern tropical Pacific sponsored by the California Department of Fish and Game, Inter-American Tropical Tuna Commission, and Scripps Institution of Oceanography.
[3] An oceanographic survey of the eastern tropical Pacific conducted by Scripps Institution of Oceanography, Inter-American Tropical Tuna Commission, Pacific Oceanic Fishery Investigations, Peruvian Naval Hydrographic Office, and the California Department of Fish and Game (October, November, December, 1955).

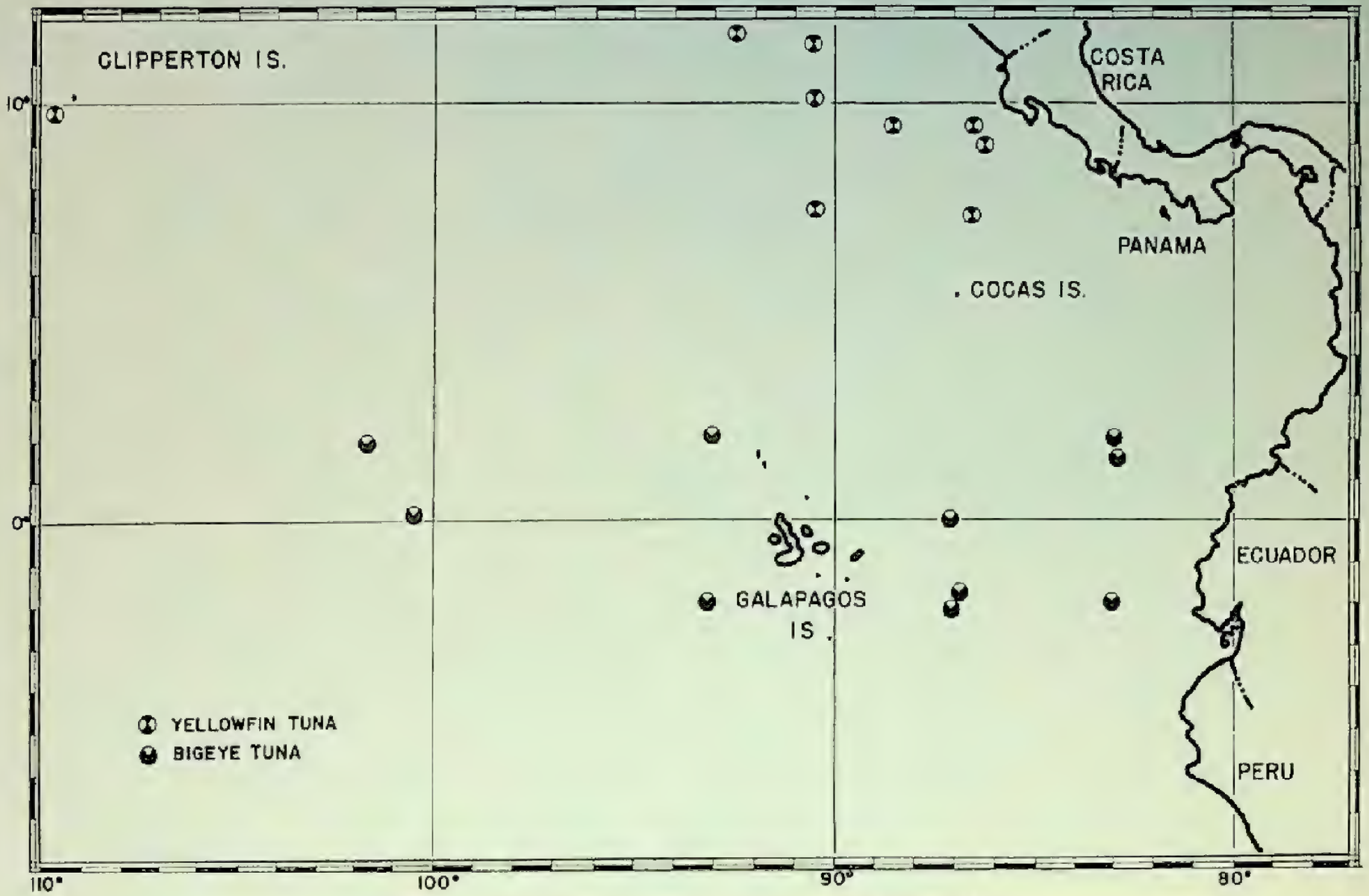

FIGURE 1. Locations of tuna stomach collections during 1955 and 1956.

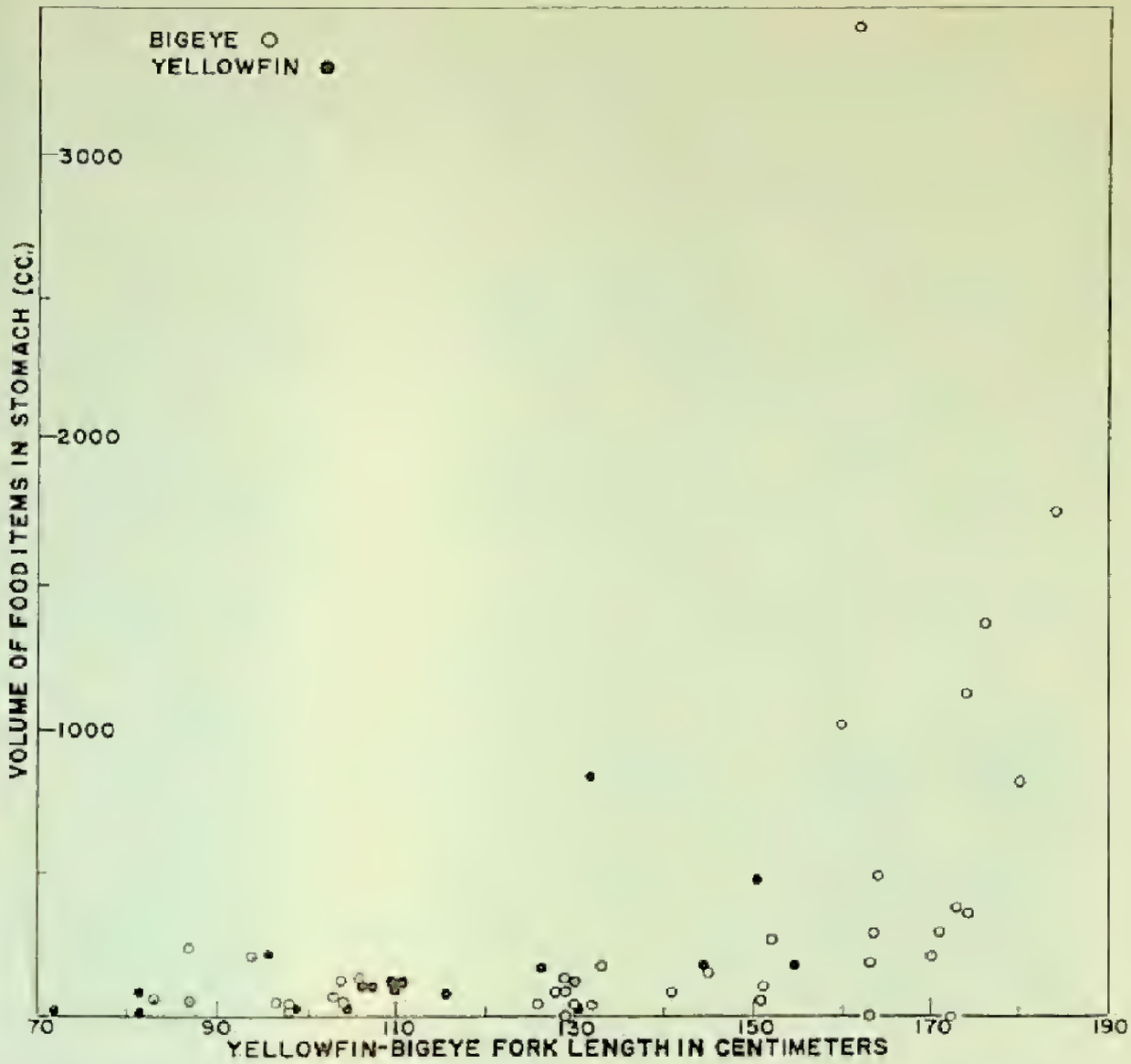

FIGURE 2. Food volume plotted against body length for 18 yellowfin and 40 bigeye tuna.

tents from escaping. All stomachs were then wrapped and frozen for study ashore.

At the laboratory the stomachs were usually thawed overnight and examined the following morning. Contents were spread in a shallow pan and arranged into groups of similar organisms. Whole items were identified as accurately as possible or practicable and individuals making up each group were counted and appropriate entries were made on a card. Volumes were measured by water displacement after excess fluid was drained off.

To represent graphically some of the major food items consumed a system was utilized wherein the percent of total volume is combined with the percent frequency of occurrence (Tester, 1932) (Figure 3). The resultant two-dimensional rectangle gives a relative comparison of the major food components.

Most of the tuna used in this sudy were captured between 7 a.m. and 3 p.m. None of the stomachs contained completely unidentifiable material. In fact, most contents were in relatively good condition, and showed only superficial digestion.

RESULTS

Food Habits of Bigeye Tuna

Fish, mollusks and crustaceans had been eaten by the 40 bigeye tuna examined (Table 1). Among the most abundant identifiable items were 104 argonauts, 96 snake mackerel, 64 *Myctophum affine*, and 40 stalk-eyed swimming crabs.

Squid contributed over 60 percent of the volume, and occurred in 70 percent of the stomachs. Fish, though comprising only 21 percent of the volume, were ingested by 75 percent of all bigeye sampled. Portunid crabs and octopods made up the remaining major items utilized as food (Figure 3).

Sizes of Food Organisms

Food organisms varied in size from small fish and cephalopods displacing two cc. of water to jumbo squid (*Dosidicus gigas*) displacing 3,300 cc.

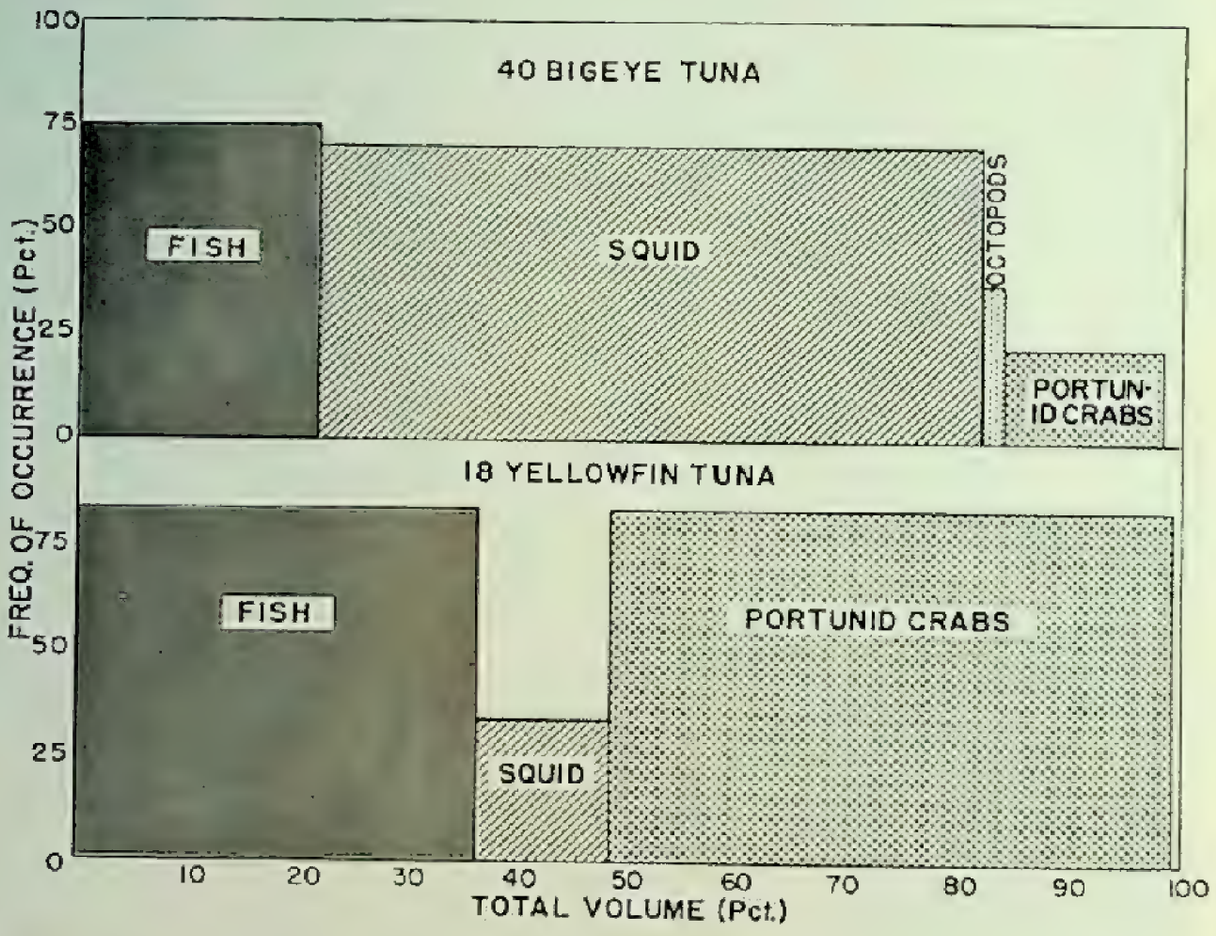

FIGURE 3. Major food items compared by plotting percent frequency of occurrence against percent of total volume.

TABLE 1

Items Found in the Stomachs of 40 Bigeye Tuna Taken By Longline Gear From the Eastern Pacific During 1955 and 1956

Item	Number of items	Frequency of occurrence		Volume	
		Number	Percent	Water displaced cc.	Percent of total
ARTHROPODA					
Crustacea		**10**	**25.0**	**2,112**	**15.1**
Decapoda					
Portunidae					
Portunis affinis	13	1	2.5	40	0.3
Euphylax dovii	40	5	12.5	1,592	11.4
Unident. portunids	6	3	7.5	370	2.6
Decapod remains	?	1	2.5	110	0.8
MOLLUSCA					
Cephalopoda		**37**	**92.5**	**8,836**	**63.2**
Decapoda		28	70.0	8,449	60.4
Onychoteuthidae					
Unident.	22	2	5.0	205	1.5
Ommastrephidae					
Dosidicus gigas	1	4	10.0	6,950	49.7
Thysanoteuthidae					
Thysanoteuthis rhombus	1	1	2.5	135	1.0
Unident. decapods	68	22	55.0	1,137	8.1
Decapod remains	4+	2	5.0	22	0.2
Octopoda		15	37.5	274	2.0
Argonautidae					
Argonauta sp.	104	11	27.5	221	1.6
Unident. octopods	27	4	10.0	53	0.4
Unident. cephalopods	6	1	2.5	38	0.3
Cephalopod remains	24+	4	10.0	75	0.5
VERTEBRATA					
Pisces		**30**	**75.0**	**3,015**	**21.6**
Myctophidae					
Myctophum aftine	61	4	10.0	185	1.3
Unident. myctophids	5	1	2.5	13	0.1
Trachipteridae					
Trachipterus sp.	1	1	2.5	1,300	9.3
Carangidae					
Naucrates ductor	3	2	5.0	78	0.6
Gempylidae					
Gempylus serpens	96	18	45.0	667	4.8
Gempylid remains	3+	2	5.0	32	0.2
Katsuwonidae					
Auxis sp.	1	1	2.5	487	3.5
Uranoscopidae					
Kathetostoma averruncus	1	1	2.5	5	T
Brotulidae					
Unident. brotulids	9	5	10.0	26	0.2
Linophyrnidae					
Unident. linophyrnids	2	2	5.0	3	T
Lophiidae					
Chirolophius sp.	17	8	20.0	71	0.5
Unident. lophiids	1	1	2.5	5	T
Unident. fish and remains	37+	10	25.0	143	1.0
MISC. UNIDENT. MATERIAL	4+	4	10.0	26	0.2
Total				13,989	

In general the smaller bigeye tuna ate smaller food items than did larger individuals (Figure 4). Items in the stomachs of fish shorter than 160 cm. averaged less than 7.5 cc. each. The 86 cc. displacement

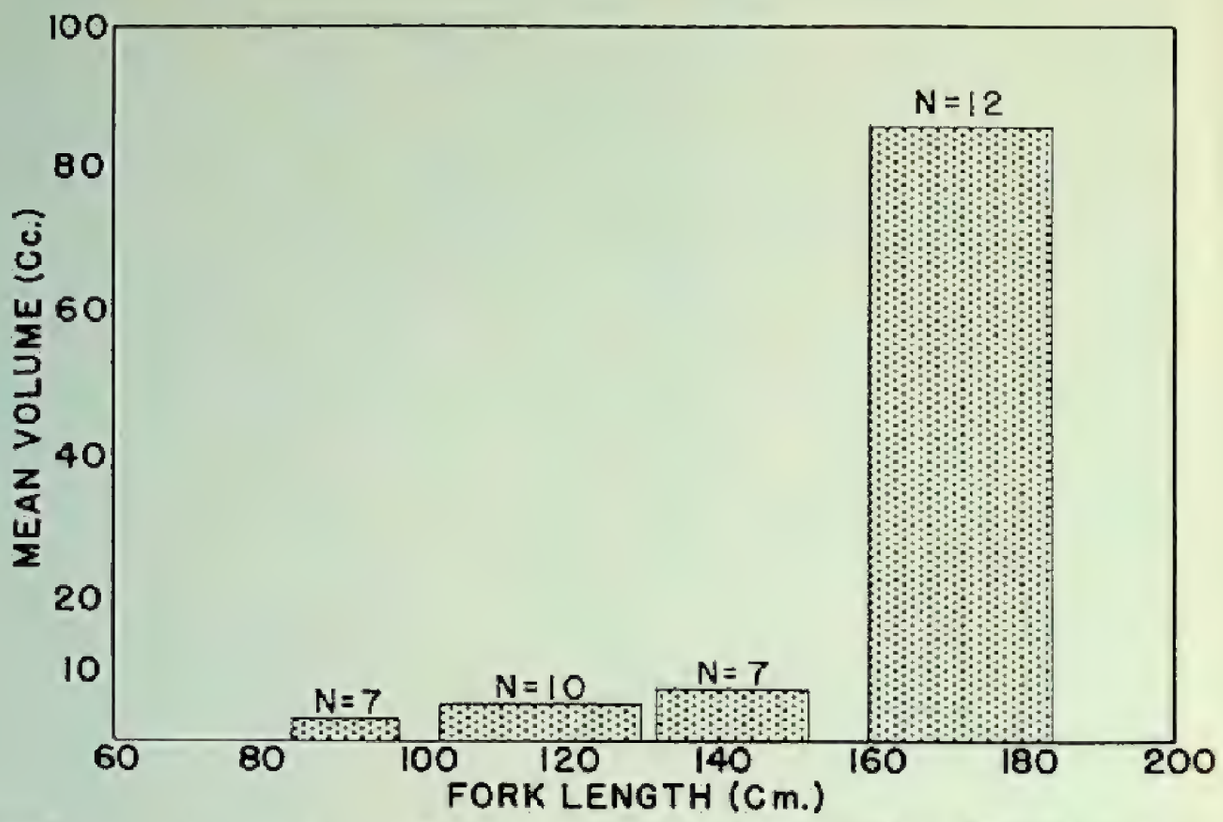

FIGURE 4. Mean volume of food items utilized by bigeye tuna from four different size groups.

per item for bigeye longer than 160 cm. was primarily because of four jumbo squid (1,000 to 3,300 cc.), although there was a definite increase in the mean size of other items within each major group.

Changes in Food Habits With Tuna Size

To investigate food habits of different sized fish the food data were summarized by size groups (Figure 5). Though the number of stomachs in each group is small it is possible to infer some changes in feeding habits of bigeye associated with growth.

Fish were very important in the diets of the smallest tuna (83-98 cm. group) by volume and frequency of occurrence (62.8 and 100 percent respectively), but fell off gradually to 17.2 percent by volume for the largest fish (160-184 cm. group). Squid, on the other hand, were increasingly important to the larger tuna, making up 20.6 percent by volume of the contents found in the 83-98 cm. group and 67.5 percent for the 160-184 cm. group. This apparent preference for squid by large bigeye is also evidenced in Juhl's (1955) notes on tuna feeding in the tropical eastern Pacific. Squid comprised 86 percent of the total food volume of four bigeye 151 to 181 cm. long, while fish and portunid crabs made up the remaining 14 percent.

Stomach volumes plotted against body length, also reflected a change in food habits as the tuna increased in size (Figure 2). Total volumes increased markedly for bigeye longer than 160 cm. This appears to result from the ability of large subsurface tunas to feed on such "high

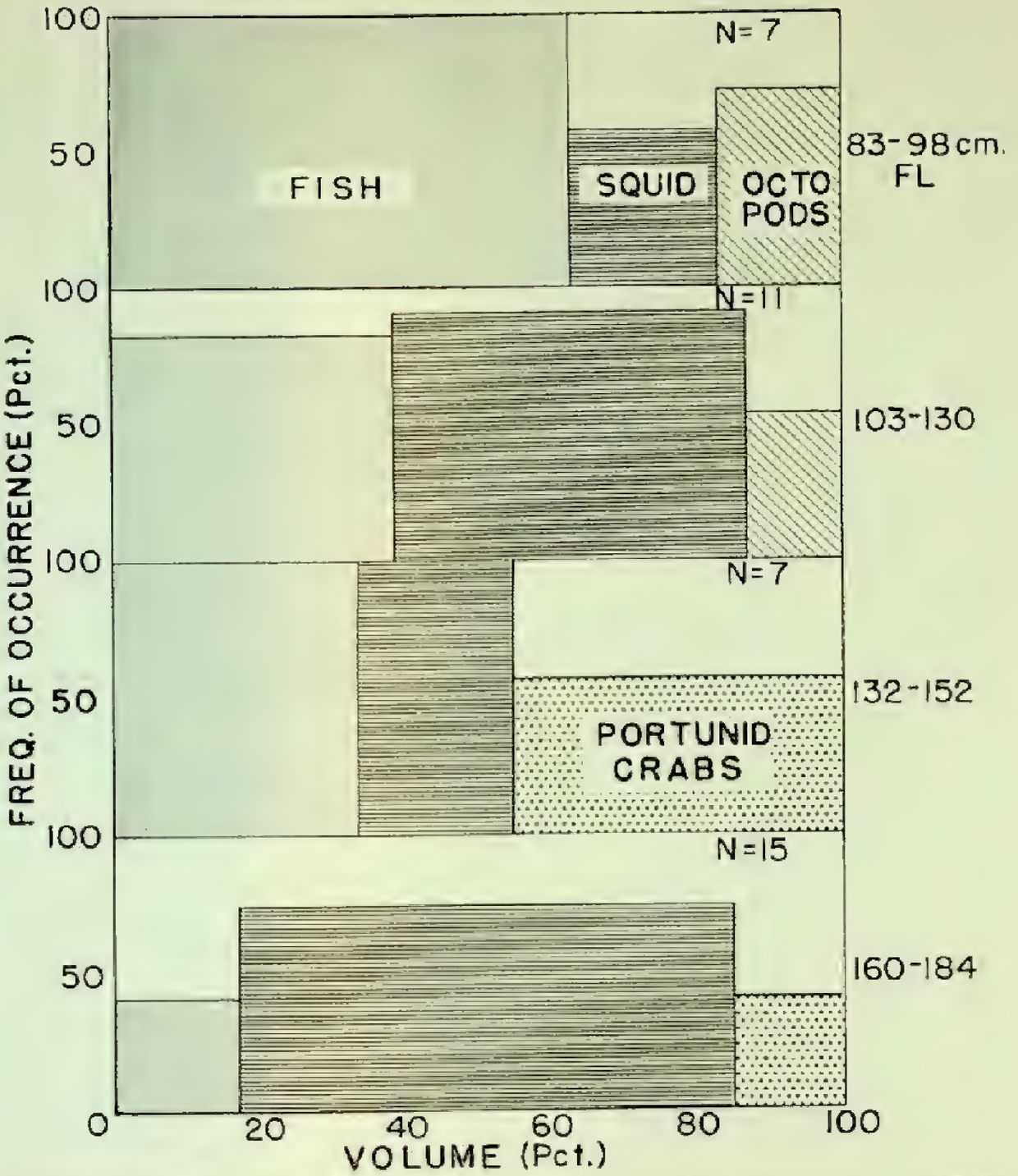

FIGURE 5. Graphic comparison of major food items utilized by bigeye from four different size groups.

volume" organisms as jumbo squid, portunid crabs, and ribbonfish (*Trachipterus* sp.).

To provide insight into whether or not the greater volumes noted in the stomachs of the larger bigeye indicated more intensive feeding (relative to body size) food volume per unit of body weight was plotted against total body weight, and the data fitted by a least-squares trend line. These data indicate an increase in the average stomach content per unit of body weight (cc./lb.) with increase in size of fish (Figure 6). This is surprising in view of the fact that small fish almost always consume more food per unit of body weight than large fish (Ricker, 1946).

Variations in Stomach Volumes With Area of Catch

Bigeye stomach samples were taken from two general areas: west of the Galapagos Islands within the bounds of the westerly flowing South Equatorial Current and between the Galapagos Islands and Ecuador straddling a transitional zone incorporating cool nutrient-rich waters of the Peru Current and warmer waters from the north. Vessels of the Eastropic expedition found considerably higher levels of productivity near the northern edge of the Peru Current. High bigeye catches experienced here compare favorably with some of the best catches in other parts of the central and western Pacific (Mais and Jow, ms.). Holmes et al. (1957) also encountered high surface primary production, as measured by C^{14}, in the Peru Current area.

The higher biological production exhibited in this "transitional zone" seems also to be reflected in the tuna stomach content volumes from there (Figure 6). Fish sampled from the Peru Current had consumed more food per pound of body weight than those taken from the area west of the Galapagos Islands.

Discussion

Squid are very important in the diet of sub-surface bigeye tuna. In this study, 70 percent of the stomachs contained squid equivalent to 60 percent of the total food volume. Fish, were also important, occurring in 75 percent of the stomachs, but due to their smaller size they comprised only slightly more than 20 percent of the total food volume consumed. The remaining foods observed were portunid crabs, octopi and miscellaneous unidentifiable items (Table 1).

King and Ikehara (1956) in their comparative study of bigeye and yellowfin food habits in the central Pacific found fish and squid the primary food items. They found fish (62 percent by volume) considerably more important than squid (33 percent) in the diet of bigeye. This is in contrast to our results, but the difference may be explained by the presence of jumbo squid in stomachs of some of the eastern Pacific bigeye. This squid is robust and massive, sometimes reaching several feet in mantle length (Berry, 1912). The largest encountered in bigeye stomachs had a mantle length of 45 cm. and displaced 3,300 cc. of water. Jumbo squid have been recorded off the coast of Chile, Peru, and eastern Australia (Berry, 1912) but apparently are not

TABLE 2

Comparison of Stomach Volumes of Bigeye Taken in the Central and Eastern Pacific

Locality of capture	Bigeye longer than 140 cm.				Bigeye shorter than 140 cm.			
	Mean length (cm.)	Number of stomachs	Mean stomach volume (cc.)	Mean vol./lb. weight	Mean length (cm.)	Number of stomachs	Mean stomach volume (cc.)	Mean vol./lb. weight
Central Pacific[1]	160	103	141.6	0.8	122	63	122.4	1.4
Eastern Pacific	164	20	613.3	2.7	111	20	86.2	1.5

[1] From King and Ikehara, 1956.

TABLE 3

Items Found in the Stomachs of 18 Yellowfin Tuna Caught on Longline Gear in the Eastern Pacific During 1955 and 1956

Item	Number of items	Frequency of occurrence		Volume	
		Number	Percent	Water displaced cc.	Percent of total
ARTHROPODA					
Crustacea	**245**	**15**	**83.3**	**1,481**	**50.8**
Decapoda					
Portunidae					
Portunis affinis	196	6	33.3	906	31.1
Unident. portunids	49	10	55.5	573	19.7
Portunid remains	?	1	5.6	2	0.1
MOLLUSCA					
Cephalopoda	**74**	**11**	**61.1**	**376**	**12.9**
Decapoda		6	33.3	353	12.1
Unident. decapods	70	4	22.2	263	9.0
Decapod remains	4+	4	22.2	90	3.1
Octopoda		1	5.5	8	0.3
Argonautidae					
Argonauta sp.	1	1	5.5	8	0.3
Cephalopod remains	3+	4	22.2	15	0.5
VERTEBRATA					
Pisces	**37**	**15**	**83.3**	**1,057**	**36.3**
Exocoetidae					
Oxyporhamphus micropterus	1	1	5.6	45	1.5
Myctophidae					
Myctophum affine	1	1	5.6	3	0.1
Carangidae					
Naucrates ductor	3	2	11.1	44	1.5
Echeneidae					
Remoropsis brachyptera	1	1	5.6	80	2.7
Gempylidae					
Gempylus serpens	2	2	11.1	12	0.4
Katsuwonidae					
Auxis sp.	2	1	5.6	750	25.7
Katsuwonid remains	?	1	5.6	26	0.9
Syngnathidae					
Hippocampus sp.	1	1	5.6	5	0.2
Callionymidae					
Callionymus sp.	2	1	5.6	3	0.1
Lophiidae					
Unident. lophiid	6	2	11.1	10	0.3
Balistidae					
Balistes sp.	4	1	5.6	19	0.7
Unident. balistid	1	1	5.6	2	0.1
Unidentifiable remains	16+	9	50.0	58	2.0
Total				2,914	

found in the central Pacific. It was not observed in the stomachs of over 1,000 bigeye and yellowfin tuna from this area (Reintjes and King, 1953 and King and Ikehara, 1956). The presence of this squid in the eastern Pacific and the apparent absence of an equivalent form in the central Pacific may be responsible for the contrast in the importance of squid as tuna food, and may explain the considerably greater stomach volumes of bigeye from the eastern Pacific (Table 2).

Data from operation *Longline* indicate that sub-surface tunas are considerably larger than those taken at the surface by the commercial

tuna fishery (Wilson and Shimada, 1955). The reason for this is not known though it has been hypothesized that feeding habits of the larger fish may be a factor.

Since squid are increasingly important in the diet of tunas as they become older and larger, their deep-living diurnal habits very likely influence the vertical distribution of tunas. Though little is known of squid ecology they apparently spend most of the daylight hours at sub-surface levels and move to the surface at night to feed. Observations off California during 1934 and 1935 indicated that jumbo squid are quite versatile, swimming close to shore as well as inhabiting the depths some miles out to sea (Clark and Phillips, 1936).

Food Habits of Yellowfin Tuna

The area off Costa Rica has long been productive in the surface yellowfin tuna fishery and is of special interest because a "thermal anticline" enriches the upper layers of the sea there.

Food of 18 yellowfin tuna taken from this area consisted of portunid crabs, fish and cephalopods (Table 3).

Portunid crabs contributed over 50 percent to the total food volume and occurred in 83 percent of the stomachs. Fish appeared in an equal number of stomachs, but accounted for only 36 percent of the volume. Cephalopods, though low in volume (13 percent of total), were found in 33 percent of the stomachs (Figure 3).

King and Ikehara (1956) found that bigeye and yellowfin tuna have similar food habits when occupying the same general area. Our data do not lend themselves to such comparisons because of the small yellowfin sample size, and differences in areas of catch. Furthermore, it is thought that many of the yellowfin from the vicinity of the

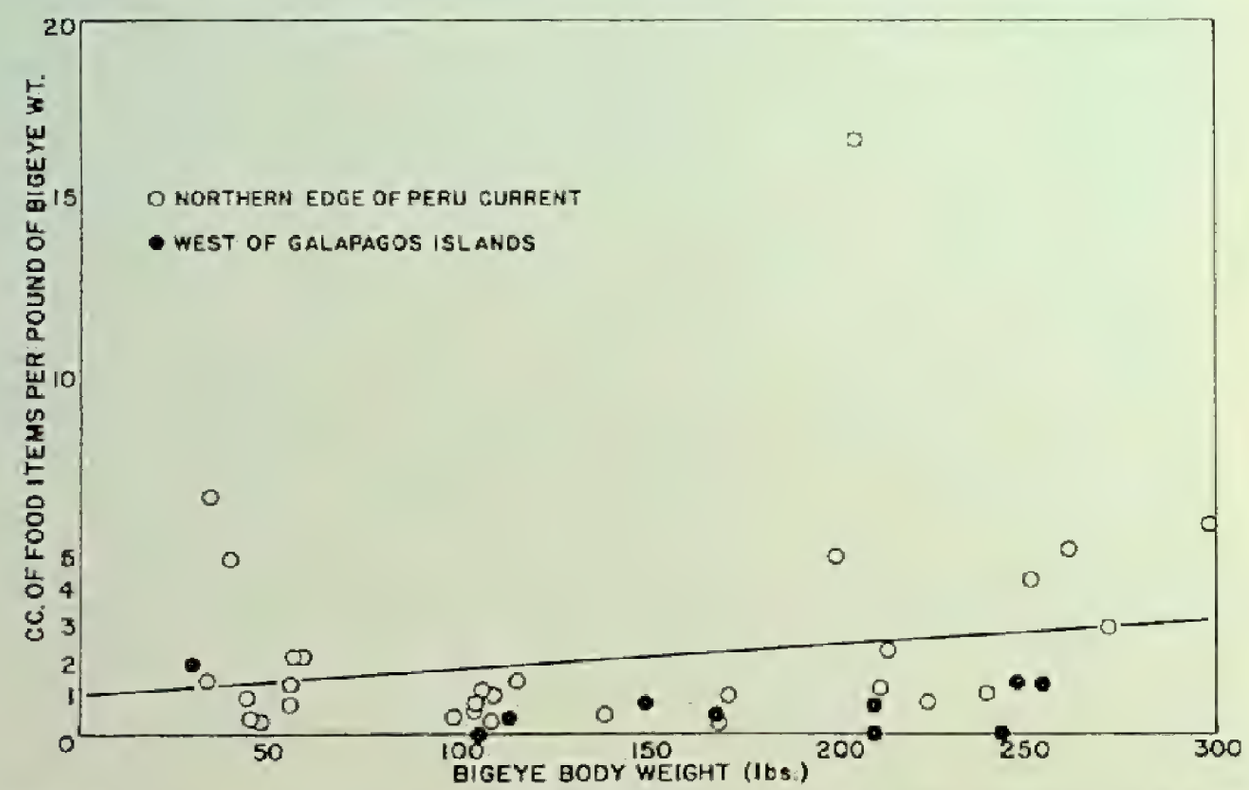

FIGURE 6. Volume of food items per pound of body weight compared with total body weight based on stomach contents of 40 bigeye tuna. Line fitted to points by method of least squares to show general trend of the data.

"thermal anticline" off Costa Rica were caught near the surface (Mais and Jow, ms.). Many of these yellowfin were probably captured as the gear passed through the surface stratum during setting and retrieving.

Portunid crabs are undoubtedly an important item in the diet of yellowfin tuna. Juhl (1955), in reporting on feeding habits of yellowfin from the tropical eastern Pacific, also found these swimming crabs to be a major item. Tuna fishermen at times encounter great quantities of them and a stalk-eyed swimming crab (*Euphylax dovii*) occurs in such quantities that it is sometimes collected as live bait in lieu of anchovetas or sardines (Garth, 1946).

SUMMARY

1. Stomach contents from 40 bigeye tuna and 18 yellowfin tuna were analyzed quantitatively.
2. Tuna were captured by longline gear during expedition *Eastropic* in 1955 and a follow-up cruise in January and February of 1956. Yellowfin were taken in the vicinity of Costa Rica and Clipperton Island. Bigeye were captured near the equator from Ecuador to 500 miles west of the Galapagos Islands.
3. Bigeye had fed primarily on squid, fish and portunid crabs. Squid are very important in the diet of sub-surface bigeye. Jumbo squid (*Dosidicus gigas*) made up 50 percent of the total food volume.
4. As bigeye increased in size there was an increase in the mean volume of food items consumed. This appears closely related to the reliance of larger bigeye on large food items such as the jumbo squid.
5. Large bigeye had more food per pound of body weight in their stomachs than did the smaller fish.
6. Bigeye taken in the vicinity of the northern edge of the Peru Current had consumed more food per pound of body weight than had those taken west of the Galapagos Islands in the area of the South Equatorial Current.
7. Bigeye stomach volumes from the eastern Pacific seem to be considerably greater than those from the central Pacific. The presence of jumbo squid in the eastern Pacific and the absence of an equivalent form in the central Pacific may be a factor.
8. The importance of squid and their deep-living diurnal habits may have an influence on the vertical distribution of large bigeye in the eastern Pacific.
9. The food of yellowfin tuna consisted of portunid crabs (51 percent by volume), fish (36 percent), and cephalopods (13 percent).

ACKNOWLEDGMENTS

I wish to thank the following people for their contributions to this report: Captain Richard Mitchell and his crew of the N. B. Scofield who spent many weeks at sea during expedition *Eastropic;* Messrs. Kenneth Mais and Tom Jow who collected the stomach material during the second cruise in 1956; Messrs. John Fitch and Harold Clemens who contributed materially throughout the preparation of this report and edited the final manuscript.

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A DIAGNOSTIC TECHNIC AND TREATMENT FOR LEAD POISONING IN SWANS[1]

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INTRODUCTION

The deposition of lead shot on the bottom of lakes and ponds during the waterfowl hunting season is so heavy in some localities that it creates an easily accessible hazard to the bottom feeding birds. The situation is intensified in areas where mud or ooze forms the subsurface, and there is no small gravel present to serve the grit needs of the birds. Tule Lake, in Northern California, is just such an area where waterfowl may ingest lead to augment the diminishing natural grit content of their gizzards.

In late winter several thousand whistling swans, *Olor columbianus* arrive at Tule Lake on their northward migration. Shortly after their arrival some exhibit varying degrees of progressive weakness followed by paralytic symptoms and death. Varying diagnoses have been offered to explain these deaths, particularly since Tule Lake is an endemic area of botulism, and in other places botulism has been shown to carry over into the winter (Rosen and Cowan, 1953).

A study was conducted on the recurrent annual losses, and the cause was established. Incidental to this study, a simple technic was employed that could be useful in the differential diagnosis of lead poisoning and botulism. The technic was part of an effective method of treatment that cures swans afflicted with uncomplicated lead poisoning.

ACKNOWLEDGMENTS

The authors wish to express their appreciation for the co-operation extended by Jean Branson, Vernon Ekedahl, and Thomas Horn; to Henry Christensen for his aid in completion of the work with the sick swans; to Robert Abney for assembling the statistics from the narrative reports; and to all other personnel of the U. S. Bureau of Sports Fisheries and Wildlife who aided in the surveys and collection of sick birds.

Special thanks are given to Warden Ned Dollahite of the California Department of Fish and Game for his assistance; to J. B. LaClair of the California Department of Agriculture for some of the chemical analyses; and to Dr. Robert Wichmann of the University of California,

[1] Submitted for publication September, 1959. This study is in part a contribution of Federal Aid in Wildlife Restoration Project California W-52-R "Wildlife Investigations Laboratory."

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School of Veterinary Medicine for his aid and corroboration in the diagnostic work.

MORTALITY RECORDS

There have been swan losses in several areas of California. The causes have ranged from recorded cases of accidental death resulting from flying into power lines to a heavy and spectacular mortality from fowl cholera (Rosen and Morse, 1959). However, the only incidence of swan mortality in California due to lead poisoning is that reported from the Tule Lake and Lower Klamath National Wildlife Refuges.

TABLE 1

Incidence of Mortality in Swans at Tule Lake and Lower Klamath Refuges *

Year	Estimated peak populations	Estimated mortality	Estimated percentage mortality
1948	15,000	200	1.3
1954	12,200	200	1.7
1955	20,000	200	1.0
1956	15,000	400	2.7
1957	9,200	300	3.3
1958	15,000	250	1.7
1959	14,000	200	1.4

* These figures are based on records of the U. S. Bureau of Sports Fisheries and Wildlife, but do not correspond exactly, having been rounded off for presentation herein.

The mortality records are summarized in Table 1. The first account of swan deaths in the files of the California Department of Fish and Game Wildlife Disease Laboratory was of February and March of 1954. The only observations made were that there were almost 200 dead swans, and that the birds exhibited gradual weakness and emaciation. At autopsy no gross lesions were recognizable, but the gizzards contained many lead shot.

The second incidence was noted in early February, 1955. Some swans were found to have died of fowl cholera and others succumbed to lead poisoning. Those birds having pasteurellosis were fat in contrast to the thin swans dying of lead poisoning. Again there were many lead pellets found in the gizzards. The cause of death was substantiated by chemical analysis of the liver and kidneys. The technic used was that described as "official" in the Association of Official Agricultural Chemists, and it is commonly referred to as the "dithizone" method.

Between the middle and end of February 1957, the swan population at Tule Lake increased from 7,500 to 9,200. The officials of the Tule Lake Refuge reported approximately 300 dead and many sick. In one area of the lake known as the Upper Sump, 25 dead swans were in a group. Upon autopsy, fowl cholera was found to be responsible for some of the mortality. It was interesting to note the difference in the condition of the birds that died from either of the two ailments; emaciated birds were invariably victims of lead poisoning, whereas the swans in good flesh had died of fowl cholera.

In February, 1958, fowl cholera caused a high mortality among waterfowl of Lower Klamath Refuge, and simultaneously in adjacent Tule

Lake about 5,000 geese succumbed to agricultural poison. These extensive losses tended to mask the comparatively low death rate among the swans. Lead poisoning was diagnosed in one swan, and two live specimens were submitted to the University of California School of Veterinary Medicine. The first bird had a gummy exudate in the lower esophagus, which on microscopic examination was found to contain large numbers of spirochetes of unknown significance. Large numbers of unidentified coccidia were found in the ceeae and there was evidence of mucosal hemorrhage. The other swan was retained in captivity, but died a few days later. Autopsy revealed that the bird suffered from an impaction of the proventriculus. Bellrose (1959) states, "The impaction of food resulting from malfunctioning of the gizzard is one of the symptoms of lead poisoning in waterfowl."

TABLE 2

Summary of Autopsy Findings in 16 Swans, January, 1959

Source	Age	Number of pellets	Examination for coccidia*	Examination for *Pasteurella* sp.
Lower Klamath	Adult	110	–	–
		9	–	–
		–	–	–
	Juvenile	27	+	–
		6	–	–
		–	+	–
		–	–	+
Tule Lake	Adult	128	–	–
		47	+	–
		21	–	–
		17	–	–
		11	–	–
		–	–	–
	Juvenile	158	–	–
		–	–	–
		–	–	–

* Those listed as positive had coccidia present but not in significant numbers.

Reports were received in January, 1959, that swans were dying on the Tule Lake and Lower Klamath Refuges. Installation personnel brought in 16 sick and dead swans for examination. The gizzards of 12 birds contained lead shot, many of which were considerably eroded. The number of pellets in the gizzards ranged from 6 to 158 (Figures 1 and 2). Microscopic examination of cecal smears revealed the presence of coccidia in three swans (Table 2). Blood smears taken of all birds and stained by Wright's method were negative for organisms with one exception and it contained bacteria morphologically resembling *Pasteurella* sp. Its pathogenicity was not confirmed. Three swans were brought to the Wildlife Disease Laboratory. One had 24 and two had 55 lead shot each in their gizzards. Kidney tissue was submitted to the Bureau of Chemistry of the California Department of Agriculture. The reported concentrations of lead were 20 parts-per-million for one, and 25 parts-per-million for each of the other two.

FIGURE 1. Lead shot in a swan's gizzard. *Photograph by M. N. Rosen, March, 1959.*

During February and March, 1959, swans continued to die. During a three-day period in March all sick and dead swans within the area were brought to the headquarters for observation and autopsy. Symptoms in the live sick swans and postmortem findings were in all instances indicative of lead poisoning in waterfowl.

SYMPTOMS AND PATHOLOGY

The most pronounced symptom of lead poisoning in waterfowl is a flaccid paralysis. This effect is striking in swans since the impaired muscles fail to support the long neck and the sick swans epitomize the term "prostrate." They are unable to take wing and their legs will not support their weakened bodies. The huge pectoral flight muscles waste away until the sternum is covered merely with a thin layer of fascia, muscle, and skin—the *keel* symptom of emaciation.

According to Nord (1941) there is "partial paralysis of the alimentary tract that inhibits normal peristalsis with a resultant clogging of the gizzard and proventriculus. Although the bird may be crammed with food it may exhibit extreme emaciation." Jordan and Bellrose (1951) found that 44 percent of their lead-poisoned penned ducks had "impacted glandular stomachs." They found that the birds may lose as much as 40 percent of their body weight. The gall bladder may enlarge five times its normal weight. As mentioned above, impaction was a relatively common finding in the swans. As a result of impaction

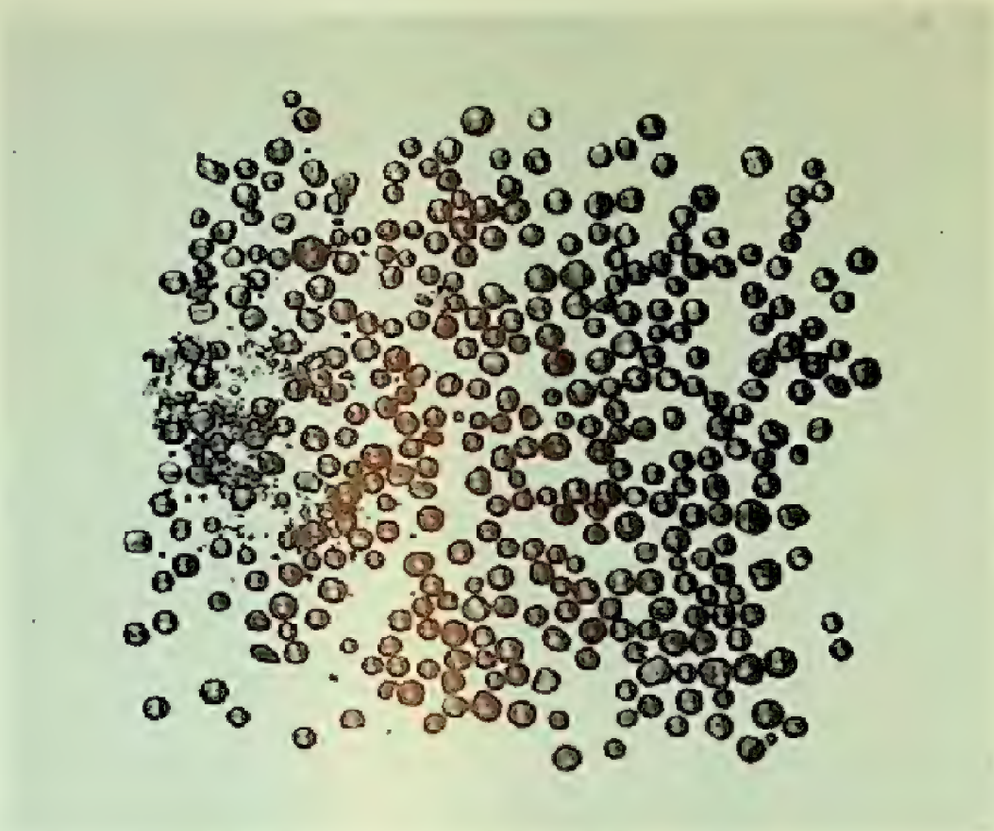

FIGURE 2. Lead shot from one swan gizzard in various sizes and in different stages of erosion. *Photograph by William Schafer, September, 1959.*

a serious complication is starvation. The enlarged gall bladders confirm the presence of the starvation syndrome. Jordan and Bellrose starved mallards and found that the symptoms and gross pathology were similar to those of lead poisoning, but without the complication of impaction. Weight losses were about equal in the ducks given lead and ducks that were starved.

Hansen, *et al.*, (1957) believed that gizzard worms (*Amidostomum anseris*) may have contributed to deaths that occurred in Canada geese due to impacted gullets. They did not incriminate lead as being primarily responsible for the mortality, but they felt that its presence coupled with the gizzard worms was the direct cause. Gizzard worms were not found in the whistling swans at Tule Lake.

A fairly common observation in swans suffering from plumbism is the blue-gray cast of the intestinal tract indicative of lead sulfide. A similar discoloration may be observed in the liver and kidney. This may occur in human cases of lead poisoning (Cantarow and Trumper, 1944). One of the most pronounced findings was the intense green or dark brown staining of the gizzard lining which may extend into the proventriculus. The feces were green and watery resulting in a greenish soiling of the feathers about the vent.

Some of the swans presented increased amounts of pericardial fluid, whereas in others the pericardial membrane appeared shriveled and adhered to the myocardium. The basophilic stippling of the erythrocytes, a common finding in lead poisoning in man, was not observed in swans. Johns (1934) associated basophilic stippling with death of

the red blood cell and the accompanying anemia in ducks, and reported that it occurred frequently in lead poisoned waterfowl. Blood smears of the Tule Lake swans showed a strong indication of anemia.

It is difficult to describe pathological lesions of lead poisoning in waterfowl. They are not consistent because there is variation in the amount of lead ingested which may result in an acute or chronic toxicity, or any of the stages in between.

DIFFERENTIAL DIAGNOSIS

Lead Poisoning and Botulism

A proven diagnosis of lead poisoning in waterfowl is a difficult undertaking. Usually it is made upon the presence of clinical symptoms and indefinite and inconsistent pathology at necropsy. The signs and symptoms of botulism are similar and may be easily confused with lead poisoning. The mere presence of ingested lead pellets is not a sufficient basis for an unequivocal diagnosis of plumbism. Quantitative chemical analysis of the soft tissues may provide sufficient information to arrive at the cause of death, or the amount detected may be insufficient to incriminate lead.

According to Salter (1952) in the early stages of human lead poisoning, lead is found mainly in the soft tissues, *i.e.* the lung, liver, and kidney. Later the metal is deposited in the bones. The liver rarely contains over 25 percent or the kidney over 10 percent of the total absorbed lead. Urine and blood of dogs suffering from lead poisoning may contain 0.6-0.7 mg. per liter, but as little as 0.08 mg. per liter is necessary to conclude that lead poisoning is present (Molpus, 1958). Hanzlik and Presho (1923) listed the minimum lethal dose as 0.16 gram of metallic lead per kilogram body weight in pigeons. The Merck Veterinary Manual (1955) quotes that the lethal amount of metallic lead for poultry is 7.2 mg. per pound of body weight.

To determine botulism intoxication, Quortrup (1943) suggested inoculation of blood from the affected birds into mice and used antitoxin-protected mice as his controls. Obviously, if all of the unprotected mice died and the antitoxin-protected mice survived, the blood of the bird contained botulinum toxin. Since on occasion false positive and false negative results have been reported, this could tend to cast doubt on the diagnosis. Quortrup improved the technic with the addition of penicillin (1946), but there are times when there is insufficient circulating toxin in the blood of the bird and a false negative result is obtained. Given sufficient specimens this difficulty may be overcome.

As mentioned above, swans dying at Tule Lake in the late winter of 1959 exhibited the typical signs and symptoms associated with lead poisoning. There were quantities of lead shot in the gizzards, and substantiation was obtained by chemical examinatioin of the soft tissues. Sick swans were emaciated, and if not paralyzed, at least they were prostrate to the extent that they could not hold up their long necks. On March 2, 1959, at about 5 p.m., two swans were inoculated with 1.5 ml. of calcium versenate intravenously. The following morning, 15 hours later, the birds were walking about holding their necks in normal position. The birds exhibited a complete and dramatic recovery except for their evident emaciation.

Calcium versenate (calcium disodium ethylene diamine tetra-acetate) is a chemical compound that forms a complex with heavy metals, e.g. lead replaced the calcium to form a soluble compound that was excreted. This is one of a group of chemicals known as chelating agents, all of which exhibit this property in varying degrees. Recently Fried *et al.* (1959) found that another chelating agent, diethylene triamine pentacetic acid protected rats against manganese poisoning to a greater extent than did calcium versenate. Perhaps it would be more effective against lead poisoning. The chelating agents accomplish detoxification not only in the blood but in the tissues as well (Fried *et al. op cit.;* Salter *op cit.*). An actual reversal occurs wherein the chemical combination in the tissues is loosened, the heavy metal is held in a complex, and is rapidly passed off in the urine.

It is quite evident from the above that calcium versenate can be used as a diagnostic aid in suspected cases of lead poisoning. However, it must be remembered that it, like other chelating agents, will combine with other heavy metals, therefore, it is necessary to rule them out. But in the case of botulism there is no effect when calcium versenate is administered.

Inoculation with this antidote for lead poisoning has no effect on the lead shot present within the gizzard. Absorption continues, and as calcium versenate is used up the symptoms reappear. Forty-eight hours after inoculation of the drug, and 24 hours after the remarkable "cure," the swans suffered a relapse. This condition may be considered as additional evidence for a diagnosis of lead poisoning.

TREATMENT

The continued use of calcium versenate eventually cleared up some of the more stubborn cases of lead poisoning in the swans. A daily dose of 1.5 ml. was inoculated in the median wing vein. In an attempt to simplify the administration of the antidote, 2.0 ml. calcium versenate was administered subcutaneously. The swans so treated did not exhibit any beneficial effect and succumbed.

The main problem that must be overcome is the removal of the lead pellets from the gizzard of the living bird. If a solution is realized, the long regimen of daily intravenous inoculations would not be necessary with a consequent saving of time and money.

Two solutions have been suggested for the problem of lead shot removal from swan gizzards. Nord (1941) used a double tube, one within the other, that created both a flushing and siphoning effect simultaneously. He reported that some of his failures were probably due to the amount of lead salts that the ducks absorbed and retained in the tissues. The apparatus he described was useful in the case of ducks, but with the extremely long necks possessed by swans the operator would experience difficulties. The tubes would have to be sufficiently flexible so as to prevent injury or perforation, and yet sufficiently rigid to be forced the entire distance from the bill to the gizzard.

According to Stokes (pers. comm. 1959), birds that have access to grit are able to void the small gravel fairly rapidly, whereas birds that have access to small amounts of grit have a tendency to retain the particles for long periods. He suggested that this phenomenon may include pellets of lead. It should be determined if the presence of

readily accessible grit would promote rapid passage of lead pellets from the digestive tract of birds.

The idea of Stokes may have merit, particularly when considered in the light of other observations. Shillinger and Cottam (1937) felt that there was a distinct relation between the incidence of lead poisoning and the availability of grit. This may be a factor, but only as it relates to the feeding habits of the particular species involved. At Tule Lake the bottom is composed of peat or organic ooze without any coarse gravel particles. Lead shot is a readily available form of accessory grinding material that might be sought and retained by the swans feeding on the tubers, roots, and sprouting potamageton. Bellrose *(op cit.)* found that the lead fired by hunters could be ingested the same year, but that by the following summer the shot penetrated through the marsh bottoms out of reach of the feeding waterfowl. Lead shot was found to be available during that time of the year that the poisoning occurs in the swans, but it disappears by summer. It is estimated that 52 tons of lead are deposited annually at Tule Lake and Lower Klamath Refuges. Dredging the bottom of Tule Lake two feet into the ooze in August, 1959, failed to yield any lead pellets. Twelve samples were taken with a nine by nine-inch Ekman dredge. All of the samples were from the most heavily hunted area of the lake. Sieving the samples also failed to disclose the presence of any form of grit.

CONCLUSION AND SUMMARY

It appears that whistling swans have been dying of lead poisoning at Tule Lake National Wildlife Refuge in the early spring each year for over a decade. The annual mortality has ranged from 1.0 to 3.3 percent of the peak population in the area. The principal cause of death has been partly obscured by fowl cholera, botulism, and agricultural poisons in other waterfowl species, and by coccidiosis and a condition diagnosed by others as idiopathic impaction of the proventriculus in the swans.

The swans suffered from a generalized weakness and flaccid paralysis. The former condition was due to starvation induced by the lead poisoning, and this emaciated the birds. Undoubtedly impaction resulted from plumbism.

At autopsy the findings were inconsistent inasmuch as the pathological picture reflected all stages of lead poisoning from acute to chronic. A fairly common finding was a blue gray cast in the intestinal tract, discoloration of the liver and kidneys, green or brown stains in the gizzard lining, and greenish soiling of the feathers about the vent caused by the thin green diarrhea.

In the majority of cases the circumstantial evidence indicating lead poisoning was the presence of lead pellets in the gizzard. The presumptive diagnosis might be confirmed by chemical analysis if sufficient lead was found in the soft tissues or in the blood.

A standard test for the detection of botulism was devised by Quortrup *(op cit.)* in which the blood of the suspected bird is inoculated into mice, some of which are protected with antitoxin. A comparable diagnostic aid successfully used at Tule Lake was the intravenous inoculation of the chelating agent calcium versenate. This chemical compound caused temporary remission of the weakness or paralysis as it combined with

lead forming a soluble complex, and was rapidly eliminated. However, the lead shot retained by the gizzard was unaffected by calcium versenate so that as more lead was absorbed the bird suffered a relapse.

Continued administration of calcium versenate effectively cured swans that had suffered from lead poisoning. Those that carried too many lead shot or that had the additional complication of impaction did not survive.

Tubes may be used to flush and siphon the lead pellets out of the gizzard. Another approach might be the use of freely accessible grit. It is thought that ingested grit may cause swans to expel lead pellets.

In cases where impaction occurs the situation is considered hopeless. However, in simplified cases, particularly those where few pellets are involved, the use of calcium versenate combined with other suggested procedures can result in a highly favorable prognosis.

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INIMICAL EFFECTS ON WILDLIFE OF PERIODIC DDD APPLICATIONS TO CLEAR LAKE[1]

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INTRODUCTION

The indirect effects of pesticides on wildlife are of growing concern to conservationists. These effects are insidious and are often entirely unnoticed or are not discernible for a long period after initial contact with a toxic material. The materials involved in this type of poisoning are usually of low acute toxicity; many are accumulative in action and are stored in animal flesh. These properties are found especially in certain members of the chlorinated hydrocarbon family of insecticides. The amount of toxic material accumulated in animal tissue may be increased over a period of years as a result of multiple contacts. Clinical symptoms or deleterious effects may appear at any time during this period. The level of accumulation of toxic material that can be tolerated before clinical symptoms occur may be different for the various animal species or individuals of the same species. Some animals are able to store large amounts of certain toxic materials in tissue with no apparent ill effects. However, continued accumulation of these materials usually affects vital functions and may eventually result in death (Wallace, 1959; Rudd, 1958).

The literature provides examples of the effects of this type of poisoning on animal populations. A few are decreased fecundity, interference with normal food chain activities, and upset of interdependent relationships of one animal species with another (Rudd, 1958; DeWitt, 1957; Genelly and Rudd, 1956; Springer, 1956).

The use of a chlorinated hydrocarbon insecticide DDD (dichloro diphenyl dichloroethane) in gnat control programs at Clear Lake, Lake County, California, resulted in a wildlife-pesticide problem (Figure 1). Involved were the effects of this insecticide on mammal, amphibian, and fish populations at the lake. A study on the effects of the gnat control programs on wildlife at Clear Lake was begun in March, 1958, by the California Department of Fish and Game and is scheduled to continue while present hazards to wildlife exist. This paper presents the results of chemical analyses of specimens collected at Clear Lake and information obtained from investigations in the area.

[1] Submitted for publication October, 1959. A contribution of Federal Aid in Wildlife Restoration Project California W-52-R, "Wildlife Investigations Laboratory."

FIGURE 1. Western Grebes—A species involved in a wildlife-pesticide problem at Clear Lake. *Photograph by William Anderson.*

ACKNOWLEDGMENTS

The effects of the control programs on wildlife could not be determined conclusively without analyses of animal tissues for the presence and amount of DDD. These analyses were made by chemists of the Food and Drug Laboratory, California Department of Public Health; and the Bureau of Chemistry, California Department of Agriculture. We wish to thank the personnel from these laboratories not only for the actual chemical analyses, but also for their assistance in assessing the significance of the analyses. Guidance was provided by staff members of the Department of Fish and Game, Department of Public Health, and Department of Agriculture in planning various phases of the study. The collection of specimens was made by Game Management, Inland Fisheries, and Wildlife Protection personnel of the Department of Fish and Game. Assistance with these collections was also provided by employees of the Lake County Mosquito Abatement District. The study was enhanced by the co-operative attitude of the agencies concerned with this problem. Critical review of this manuscript was made by Dr. Robert L. Rudd.

PHYSICAL DESCRIPTION OF CLEAR LAKE

Clear Lake is an irregularly shaped body of fresh water approximately 19 miles long and seven miles wide (Figure 2). The lake is about 1,325 feet above sea level and has a surface area of approximately 41,600 acres. It has an upper and lower portion connected by a narrows that is less than one mile wide. Clear Lake is relatively shallow with maximum depths of 30 feet in the upper portion and 50 feet in the

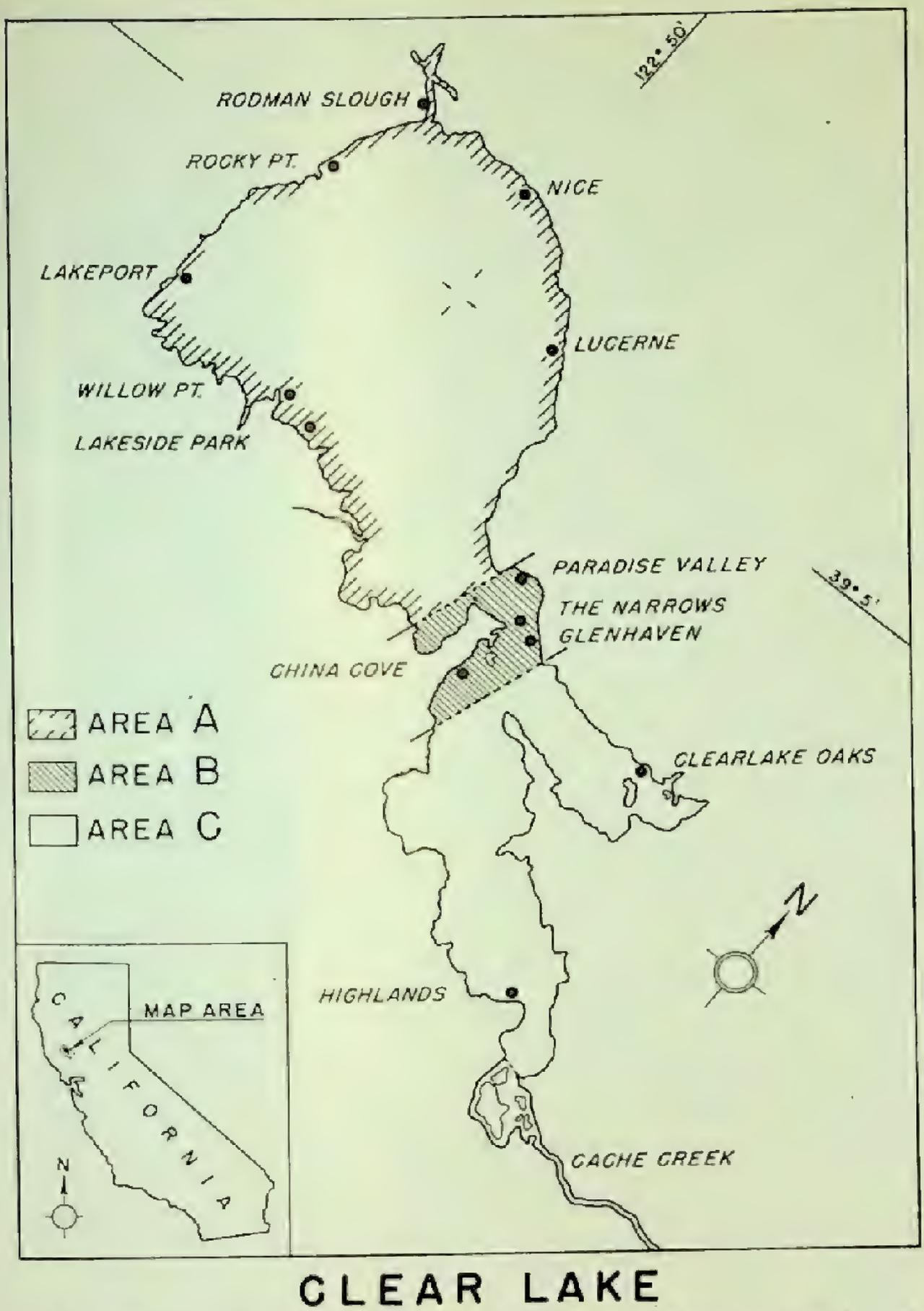

FIGURE 2. Map of Clear Lake showing locations of animal collections. Drawing by Cliffa Corson.

lower portions. The marginal slope of the lake bottom is gradual in most places, especially in the larger upper portion where it is saucer shaped. The deposits on the bottom are predominately soft, deep, black

ooze except for a few beaches and a portion of Konocti Bay, which are largely volcanic gravel.

Mountains of the Coast Range surround the lake and slope to the water's edge along most of the shoreline. The peaks of some of the highest mountains in the area are over 4,000 feet in elevation. Several alluvial plains fan out into the lake on the west side.

An estimate of the average amount of water during late summer is 300 billion gallons or 850,000 acre feet. The lake level fluctuates with seasonal precipitation and the demands for water from agricultural and domestic interests. Occasionally the level ranges from 8 or 10 feet above to one to two feet below the zero reading on a scale indicator used to measure variation in surface level (Lindquist and Deonier, 1943).

The annual bottom temperatures range from 45 to 78 degrees F. Compared with other mountain lakes, Clear Lake is rather turbid most of the time. The distance at which Secchi Disks can be seen may vary from 5 to 75 inches (Walker, 1949).

HISTORY OF GNAT CONTROL AT CLEAR LAKE

The periodic appearance of large numbers of gnats, *Chaoborus astictopus*, during the summer has presented a problem to Clear Lake residents for many years and has had an adverse effect on the large resort business. The annoyance caused by these insects is due wholly to their extreme abundance and attraction to light. These gnats are closely related to mosquitoes but are not bloodsuckers and probably do not feed as adults (Herms, 1937). Concern over the outbreaks of gnat populations led to occasional studies over a period of years to determine methods of control. The study of the biology and methods of controlling this insect has been extensive. Adverse effects on fish life have been considered in the planning of chemical control programs. The following is a brief chronological account of activities relating to gnat control at Clear Lake from 1916 until the initiation of this study in 1958.

Between 1916 and 1941 several studies were made on the biology of the gnat. Experiments were conducted to determine the effectiveness of several larvicides and ovicides. No large scale control program developed from these experiments. The possibility of using native fish to control the gnat also was explored and examinations made to determine the food habits of 10 fish species. This food habit study indicated that nine of the species examined consumed gnat larvae or pupae and/or adults at some time during the year. Although fish were found to consume great quantities of gnats, it was apparent that some other method of control was required.

During the war years all work was suspended, but in 1946 research to develop a satisfactory control program was resumed. Laboratory experiments with newly-developed chlorinated hydrocarbon insecticides indicated that these materials could be used to control the gnat. Two chemicals, DDT and DDD, were found to have desirable properties and were selected for further study.

Studies made on the toxicity and effect of these chemicals on fish and gnat larvae in aquaria and in smaller bodies of water in the Clear Lake area indicated that DDD would provide the satisfactory gnat control with less hazard to the aquatic environment and its inhabitants

than DDT. The final selection of DDD as the larvicide to be used in Clear Lake was made after test applications of this material to nearby Blue Lake in 1947 and Detert Reservoir in 1948. DDD was reported as causing relatively low fish mortality when used at a dilution of one part of insecticide to 70 million parts of water (Lindquist and Roth, 1950). The effects of the DDD treatment of Blue Lake on bottom organisms were reported by Lindquist and Roth (1950), and on insects, fish, and plankton by Murphy and Chandler (1948). A hydrographic survey of Clear Lake was made in the winter of 1948 and 1949 by the U.S. Geological Survey to provide necessary information on the volume of water and the physical properties of the lake. Results of this survey were used in computing desired insecticidal dosages and in planning the actual DDD application.

The first large scale DDD treatment of Clear Lake was made in September, 1949; 14,000 gallons of chemical concentrate were used. The insecticide was prepared by a chemical company according to the following formula: DDD (TDE) 30 grams, emulsifier 30 ml. and xylene 72 ml. (Lindquist *et al.* 1951). The material was applied from six barges towed by tug boats. Final dilution in the lake water was estimated at one part of active insecticide to 70 million parts of water. Additional treatment of 20 small lakes and reservoirs within 15 miles of Clear Lake was made. It was determined that a 99 percent kill of gnat larvae resulted from this treatment. As a result very few gnats were observed for two years.

In July, 1951, gnat larvae were found by a night plankton tow, for the first time since the 1949 treatment. The numbers of gnat larvae and adults increased; and a second DDD treatment of the lake was made in September, 1954. The concentration of active insecticide in the lake water shortly after this treatment was greater than the first treatment and was estimated to have been one part of active insecticide to 50 million parts of water. Rate of larval kill was again estimated at 99 percent. All mud samples taken later that year were negative for *Chaoborus* (Brydon, 1955.)

In December, 1954, 100 western grebes, *Aechmophorus occidentalis*, were reported dead, and specimens were sent to the Department of Fish and Game Disease Laboratory. (Any mention of grebes in the text unless otherwise designated refers to western grebes.) Infectious disease was not detected in these specimens. In March, 1955, more dead grebes were reported, and results of autopsies on specimens submitted to the disease laboratory were also negative for infectious disease.

Gnat populations increased during 1955-56; and a third treatment of Clear Lake was made in September, 1957. DDD was again applied at the rate of one part of active insecticide to 50 million parts of water. Gnat control was considered not to be as successful as after previous treatments. The lower rate of success was attributed by some observers to inimical weather conditions during application and by others to a buildup of resistance to DDD by the gnats. During December, 1957, approximately 75 grebes were reported dead on the shores of Clear Lake. A few weeks after this report two sick grebes were submitted to the disease laboratory. No infectious disease was found. Two sections of fat from these birds were submitted to the Bureau of Chemistry, California Department of Agriculture, for toxicological examination.

Results of chemical analysis of the fatty tissue indicated DDD was present at the unusually high concentration of 1,600 p.p.m. (parts per million). Contaminated food was suspected to be the cause of death.

Accordingly in March, 1958, a fish collection was made by personnel of the Lake County Mosquito Abatement District. Samples were submitted for toxicological examination. They included single specimens of carp, *Cyprinus carpio*, white catfish, *Ictalurus catus*, black crappie, *Pomoxis nigromaculatus*, brown bullhead, *Ictalurus nebulous*, largemouth bass, *Micropterus salmoides*, and Sacramento blackfish, *Orthodon microlepidotus*. Visceral fat was analyzed by Department of Agriculture chemists. The amount of DDD found in the fat ranged from 40 p.p.m. in the carp to 2,500 p.p.m. in the brown bullhead. After the results of these analyses were received by the Department of Fish and Game the present study was initiated and is being continued.

METHODS

Animals collected for chemical analyses were taken by conventional methods. Fish were either netted in gill nets, seines, or fyke nets, or were taken by hook and line. Birds collected for testing were shot; and bullfrogs, *Rana catesbeina*, were provided by the local warden. Samples of fish for chemical analysis were usually skinned and filleted. Some fish samples were submitted whole except for being eviscerated, but they proved difficult to grind in preparation for chemical analysis. Visceral fat was dissected from the internal organs of certain fish. Fish from two of the three collections made were classified according to brood year and age groups by accepted methods (Marzolf, 1955; Lagler, 1952). No fish in the second collection were aged. However, an attempt was made to collect older fish of similar size.

The quantitative analysis for DDD in grebe flesh was made from composite samples of visceral and subcutaneous fat. Samples of frog tissues were analyzed from visceral fat only. Flesh samples that could not be analyzed in a fresh condition were frozen and stored until analysis could be made.

The analytical procedure used for detection of DDD was a modification of the Scheeter-Haller Method for color development (Pontoriero and Ginsburg, 1953). Removal of interfering substances such as fat was accomplished by use of the Davidow exchange column following extraction of the sample with solvent (Davidow, 1950), or with the use of dimethylformamide (Burchfield and Sterrs, 1953). The presence of DDD was determined by specific color development. The only commonly encountered compounds that give the same color reactions are nontoxic isomers and metabolites of DDT and DDD. To be sure that isomers or metabolites were not involved in the color determination, bio-assays using house flies, *Musca domestica*, were done on the first fish samples. Results of these bio-assays established the presence of a toxic substance, and no additional bio-assays were made. Since no appreciable amount of DDT had been used in the area, the toxic substance in all analyses was assumed to be DDD.

PROCEDURE AND RESULTS

Samples of flesh tissue for chemical analyses were limited to specimens collected in the Clear Lake area. Some life history data on bird and fish species were also obtained. The original selection of species to be sampled was based on both availability and suspected DDD contamination. Animals believed to have come in contact with DDD and which were readily available were collected first. Information derived from analyses of samples of the first two collections indicated that certain species could be used as indicators of maximum DDD concentrations. Subsequent collections were planned to include primarily these species.

The number of animals taken during each collection was determined by one or more of the following: (1) the total number of samples that could be readily analyzed by co-operating agencies, (2) the availability of the animal to be sampled, and (3) the number needed to provide an adequate sample. The number of analyses varied with each collection but was always less than 25. Analyses were made of composite as well as single samples. Samples were considered adequate when the data obtained satisfactorily clarified specific problems. All fish collected were apparently healthy and exhibited no symptoms of being affected by the insecticide. Symptoms of fish poisoned by chlorinated hydrocarbons were described by Henderson *et al.* (1958).

First Collection

Samples obtained during the first collection, May, 1958, were composed entirely of fish taken from two locations, one at each end of the lake. The basic information desired from these samples included: (1) the distribution and comparative levels of contamination of DDD in fish, (2) the effect of cooking on breakdown of this chemical, (3) the amount of DDD in different fish species, and (4) the percentage of the fish population that was contaminated with DDD. The results of chemical analysis of this collection are given in Table 1. For purposes of simplification only common names will be used in the tables.

Results of these analyses regarding the distribution and comparative levels of contamination of DDD in fish flesh agreed with findings of other investigations that most of the insecticide is accumulated in fatty tissue (U. S. Dept. Pub. Health, Educ. and Welfare, 1955; Bann *et al.* 1956; Metcalf, 1957). The amount of chemical in visceral and flesh fat from the same samples was similar. Two samples of edible flesh were wrapped in aluminum foil and baked at 400 degrees F. for one hour prior to analysis. There was very little breakdown of DDD, and the major change due to cooking was loss of water and transfer of some fat containing DDD from the flesh to the cooking container. Those species containing the highest concentration of DDD in edible flesh were brown bullhead, largemouth bass, and black crappie. It was apparent that larger samples taken from additional locations would be necessary to obtain more precise information regarding the extent of DDD contamination of the fish at Clear Lake.

TABLE 1

Analysis of Fish Flesh From Collection Made in May, 1958

Species	Year class	Age group	Parts per million of DDD				
			Visceral fat	Edible flesh		Fat of edible flesh†	
				Raw	Cooked	Raw	Cooked
Bluegill	1955	III	–	0.52	–	255	–
	1956	II	–	5.27	–	293	–
	1957	I*	175	6.75	–	278	–
	1957	I*	254	7.14	–	350	–
Black crappie	1956	II*	2,690	115.00	–	2,840	–
Brown bullhead	1954	IV	548	79.90	60.3	1,110	1,010
	1955	III	342	11.80	–	218	–
	1955	III	650	24.60	–	912	–
Largemouth bass	1954	IV	1,550	115.00	133.0	1,360	1,310
Sacramento blackfish	1956	II	983	10.90	–	773	–
	1956	II	–	17.60	–	475	–
Hitch	1956	II	–	10.00	–	106	–
	1957	I	–	28.10	–	763	–

* Composite of two fish; all other samples of individual fish.
† Fat between the muscle tissues.

Consideration was also given to possible contamination of amphibians with DDD. Visceral fat from nine bullfrogs was analyzed and found to contain 5 p.p.m. of DDD. This level of accumulation was considered low, and no further examinations of frog tissue were made.

Second Collection

The second collection, July, 1958, was also composed entirely of fish. An attempt was made to obtain a representative sample of the more numerous fish species from several key areas along the lake shore. Because of the large number collected, fish were segregated into groups of similar size and appearance instead of aging them by conventional methods. This proved unfortunate because data collected from other samples regarding age and DDD accumulation were not directly comparable. One tagged white catfish 10 years old was collected and was the only sample of known age in this collection. Results of analysis of the second collection are given in Table 2. The area designation used in this table of A, B, and C was established arbitrarily. Area A corresponds to the upper section of the lake, Area B to the central section of the lake, and Area C to the lower sections of the lake. All three areas of the lake contained DDD contaminated fish.

Of the nine fish species in the second collection the highest concentration of DDD was found in white catfish and largemouth bass. These species were chosen for sampling on all subsequent collections. Sampling of any other fish species was to be intermittent.

TABLE 2

Analysis of Fish Flesh From Collection Made in July, 1958

Species	Area	Number fish in sample	PPM of DDD edible flesh
Black crappie	A	6	5.4
	B	5	61.0
	C	1	5.8
Brown bullhead	A	25	15.5
	B	1	32.2
	C	32	24.8
Bluegill	A	24	7.3
	B	49	10.0
	C	20	6.6
Carp	A	10	51.3
	B	35	62.3
	C	4	63.8
Sacramento blackfish	A	1*	–
	B	16	20.4
	C	–	–
Hitch	A	–	–
	B	52	18.5
	C	–	–
Largemouth bass	A	1*	5.0
	B	1	97.3
	C	2	19.7
White catfish	A	11	30.4
	B	50	81.6
	C	6	129.0
Tagged catfish 10-year-old	B	1	133.0
Total	A	79	–
	B	210	–
	C	65	–

* These fish were of insufficient size to constitute a satisfactory sample for analysis

Third Collection

The third collection was made in October, 1958, and included samples of largemouth bass, white catfish, Sacramento blackfish, grebes, and plankton. Results of the analysis of these samples are presented in Table 3. The year-old group of Sacramento blackfish and largemouth bass included in this sample was hatched seven to nine months after the last DDD treatment. Flesh samples of both species, one a plankton eater (Sacramento blackfish), the other a carnivore (largemouth bass), contained significant amounts of DDD. Grebes collected were believed to be from a large population of winter visitants. At the time of the grebe collection several thousand grebes were on the lake. In the same general area four weeks prior to the collection fewer than 50 grebes were seen. The plankton samples were too small for accurate chemical analysis. Due to the inadequacy of the sample the presence or absence of DDD in plankton at Clear Lake could not be established.

TABLE 3

Analysis of Animal Flesh From Collection Made in October, 1958

Species	Year class	Age group	Percent fat in edible flesh	Parts per million DDD	
				Edible flesh	Visceral fat
White catfish	1956	II	–	22	–
	1955	III	–	26	–
	1953	V	–	64	–
	1953	V	3.0	109	–
	1953	V	–	113	–
	1953	V	4.0	142	–
	1953	V	–	178	2,110
	1953	V	9.5	196	2,375
	1950	VIII	2.0	106	–
	1950	VIII	–	111	–
	1950	VIII	–	221	–
	1949	IX	–	162	–
	1949	IX	2.1	174	–
Largemouth bass	1958	0	6.0	22*	–
	1958	0	–	24*	–
	1958	0	–	25*	–
	1957	I	–	30	–
	1957	I	–	42	–
	1951	VII	2.0	138	–
Sacramento blackfish	1958	0	1.5	7*	–
	1958	0	–	9*	–
Western grebe	Mature	–	†	–	723

* Composite samples not filleted; all other samples were fillets.
† Composite sample of subcutaneous and visceral fat.

Table 4 presents data on the amount or range of DDD found in all samples of animal flesh analyzed. The amount of DDD found in all flesh samples exceeded by many times the specified rate of dilution of active insecticide in the lake on a p.p.m. basis. All fish, bird, and frog samples contained DDD. Because of a difference in food habits it was believed that carnivorous fish accumulated a greater amount of DDD than did plankton eating fish of similar size and age.

Two additional collections have been made at Clear Lake, and the results of analysis have not been received at the time of this writing. Present plans call for the continuation of sampling at four-month intervals until the DDD contamination in animal flesh is considered by the investigators to be insignificant.

Several observations indicate a decrease in the nesting grebe population at Clear Lake since the first DDD treatment. Prior to this treatment the nesting population of grebes was in excess of 1,000 pairs (A. H. Miller, pers. com., 1959). During the nesting seasons of 1958 and 1959 less than 25 pairs were seen during surveys made by Spruill (pers. com., 1959) and the authors. Separate surveys in 1959 by Miller and Spruill each reported that nests of grebes were not found in areas where they had been in previous years. As many as 15 pairs of grebes were reported on the lake during this past nesting season but no nests or young have been found. It is not known whether these birds constructed nests that were not found or they made no attempt to nest.

TABLE 4

Range of DDD Contamination of All Specimens Collected at Clear Lake

Species	Specimens analyzed	Number of analyses	Visceral fat				Edible flesh					
					P.P.M. of DDD				Parts per million DDD			
			Analyses	Specimens	Single samples	Composite samples	Analyses	Specimens	Single samples	Composite samples	Cooked samples	Fat of cooked samples
White catfish	82	20	3	1*	1,700-2,375	–	14	14	22.0–221.0	–	–	–
			–	–	– –	–	3	67	– –	30.4–129.0	–	–
Largemouth bass	19	12	2	1*	1,550-1,700	–	6	6	5.0–138.0	– –	133.0†	1,310†
			–	–	– –	–	4	12	– –	19.7–25.0	–	–
Brown bullhead	62	10	4	1*	342–2,500	–	1	4	11.8–79.9	– –	60.3†	1,010†
			–	–	– –	–	2	57	– –	15.5–24.8	–	–
Black crappie	15	6	1	1	1,600 –	–	1	1	5.8 –	– –	–	–
			1	2	– –	2,600 –	3	11*	– –	5.4–115.0	–	–
Bluegill	100	9	2	2	175–251	–	3	3	5.3–8.5	– –	–	–
			–	–	– –	–	4	95	– –	6.6–10.0	–	–
Hitch	54	3	–	–	– –	–	2	2	10.9–28.1	– –	–	–
			–	–	– –	–	1	52	– –	18.5–	–	–
Sunfish	1	1	–	–	– –	–	1	1	5.4 –	– –	–	–
			–	–	– –	–	–	–	– –	– –	–	–
Sacramento blackfish	32	7	2	1*	700–983	–	2	2	10.9–17.6	– –	–	–
			–	–	– –	–	3	29*	– –	7.0–20.4	–	–
Carp	50	4	1	1	40 –	–	3	49	– –	51.3–62.3	–	–
			–	–	– –	–	–	–	– –	– –	–	–
Total fish	415	72	–	–	– –	–	–	–	– –	– –	–	–
Frogs	9	1	1	9	– –	5 –	–	–	– –	– –	–	–
Grebe	7	2	2	7	– –	723 –	–	–	– –	– –	–	–
Total	431	75	–	–	– –	–	–	–	– –	– –	–	–

* Includes specimens used in other analyses.

† Single analysis of one fish.

A collection of five adult grebes was made in August, 1959. There were an estimated 60 grebes on the lake at that time, and although the normal nesting season had been completed no immature birds of this species were seen. These data, although fragmentary, indicate little or no nesting success of this species during 1959. However, nests of several pied billed grebes, *Podilymbus podiceps*, and coots, *Fulica americana*, were found; and mallards, *Anas platyrhynchos platyrhynchos*, and cinnamon teal, *Anas cyanoptera* nested successfully in the area. Reasons for this reported difference in nesting success are not known.

After the 1954 and 1957 applications of DDD dead grebes were reported. Based on examination of specimens submitted to the laboratory, disease was not believed to have caused the death of these birds. Toxicological examination was not made on dead grebes in 1954. Two grebes were submitted for toxicological examination in January, 1958. Fat samples from these birds contained 1,600 p.p.m. of DDD. According to chemists of the Department of Agriculture the probable cause of death of these birds was chronic DDD poisoning. As further indication that they were poisoned, both birds exhibited nervous tremors comparable to those characterizing chlorinated hydrocarbon poisoning as described by Radeleff and Woodard (1955). Several other grebes observed on Clear Lake showed similar symptoms (Speth and Taylor pers. com., 1958).

No attempt was made to determine acute or chronic toxicity of DDD to grebes, and no reference to toxicity of any chlorinated hydrocarbon to this or related species was found in literature. However, strong circumstantial evidence indicates that grebe losses occurring after DDD treatments were caused by chronic poisoning from DDD. Differences in DDD concentrations in the fat from fish and grebes may also be interpreted to suggest that grebes show a higher susceptibility to DDD than do many fishes.

DISCUSSION

The use of DDD has affected certain wildlife species in the Clear Lake area. Dead grebes were observed following each DDD application. Various amounts of the toxic material were found in all animals examined. From what source the animals accumulated DDD and to what extent animal populations were affected by this chemical is not fully known.

At present there is no significant public health hazard involved in consumption of Clear Lake fish according to toxicologists of the State Department of Public Health. However, to assure that safe levels for human consumption of Clear Lake fish are not exceeded and to prevent the possibility of increasing the present hazard of DDD poisoning of wildlife, no further treatment of Clear Lake with DDD will be made. It is probable, therefore, that a complete understanding of this particular pesticide-wildlife problem will never be obtained. However, some of the data presented in this paper may be applicable to other problems resulting from similar pesticide applications.

Conclusive results based on chemical analyses showed that all organisms contained DDD. These results established which types of tissue had the greatest concentration of DDD, the amount of chemical found

in tissues of various species, and the extent of DDD contamination of fish in the lake.

Results based on circumstantial evidence are believed to be correct. The information collected pertaining to the chronic poisoning of grebes is not complete. It is known that these birds are subject to periodic die-offs, and such an occurrence could have reduced the nesting population at Clear Lake. Additional information will be required to relate accurately the results of chemical analyses of tissues and the cause of death of the grebes. The use of fat analysis to establish a diagnosis of poisoning can be misleading. Apparently, high levels of insecticides can be built up without harm by certain animals (Radeleff and Woodard, 1955).

Although the data are in part circumstantial, the following items indicate poisoning rather than other causes of mortality: (1) the decline in the grebe population corresponded with the period in which pesticide applications were made, (2) the absence of any known infectious disease in autopsied grebes picked up after two of the chemical treatments of the lake, (3) clinical symptoms common to poison victims were exhibited by some grebes from the lake, and (4) an abnormally high concentration of DDD was found in fatty tissue of dead grebes. Observations of dead grebes were made following each DDD application. These die-offs began one or two months after pesticide application and usually lasted several weeks. The fact that die-offs were noted during these periods only, indicates the possibility of chronic poisoning of grebes.

Assuming that grebes were poisoned by DDD, it is important to know how they obtained the toxicant. It is believed that most of the toxic materials was assimilated from ingested contaminated fish and insects. The food of grebes at Clear Lake has been reported to consist primarily of fish, with some insects included (Lawrence, 1950). The chemical could also have been absorbed through the skin or picked up from contaminated feathers consumed by the birds or from other less conspicuous sources. A more logical assumption is that the control programs resulted in the creation of "poisonous fish." The toxicant accumulated in the grebes as a result of ingesting these "poisonous fish" and other contaminated food and resulted in the death of grebes.

The accumulation of DDD in fish flesh could be correlated with food habits exhibited in normal food chain relationships. Generally speaking smaller fish accumulated less DDD on a p.p.m. basis than did larger fish. Plankton eaters accumulated less of the toxic material than carnivorous fish species of the same size. For example, flesh samples of one-year-old largemouth bass contained more than twice the amount of DDD than flesh samples of a one-year-old Sacramento blackfish. Flesh samples from three to seven-year-old bass contained up to five times as much DDD as a one-year-old bass and 20 times as much as a one-year-old Sacramento blackfish. The theory of DDD transmission through a food chain would be more acceptable if the presence of DDD in plankton organisms could have been established.

It is assumed that certain species of Clear Lake fish such as white catfish and largemouth bass possess a greater tolerance for DDD than do grebes. This is based on results of analysis of fatty tissue. Analysis of visceral fat from apparently healthy largemouth bass and white

catfish indicated accumulation of DDD at levels as high as 2,275 p.p.m. and 1,700 p.p.m., respectively. The highest concentration of DDD found in grebe tissue—1,600 p.p.m.—was from birds believed killed by chronic DDD poisoning.

Several theories may be offered regarding further aspects of the Clear Lake problem. Two of these theories pertain to possible consequences of further DDD treatments. The first relates to the establishment of resistance to DDD by various animals. After animals build up a resistance to DDD, or other chlorinated hydrocarbon insecticides, a relatively greater degree of exposure may be endured without perceptible adverse effects. Examples of resistance to chlorinated hydrocarbons in insects is well documented by Hammerstrom (1958) and Shepard (1958), but this phenomenon has not been reported in warm-blooded animals. Fish might accumulate DDD in small increments and might not be affected by small additional dosages beyond the normal toxic threshold. Presumably these fish would not be affected by additional DDD treatments.

A second theory expresses an opposing idea. This is based on the fact that certain species have already accumulated and stored large amounts of the toxic chemical, and one or more additional treatments would result in the loss of many fish. DDD already accumulated might not break down and be eliminated, and that accumulation of DDD would continue until lethal dosages were reached. In experiments with DDT conducted by Tarzwell (1950), continued applications of sublethal dosages of this material resulted in fish losses.

There may be other effects of these insecticide programs that will become evident in the future, and there are probably some effects that will never be measured. An example of this pertains to the effect of insecticides on reproduction. The accumulation of sublethal dosages of DDD by various animal species might reduce fecundity. It has been shown by other investigators that feeding DDT to quail and pheasants resulted in lower than normal rate of hatch and a greater number of malformed progeny than was found in control birds (Genelly and Rudd, 1956; DeWitt, 1955).

If it were true that certain fish have at present accumulated DDD to a level slightly below the critical toxic level, then such fish could be endangered by further consumption of other contaminated fish. This would mean that a die-off of fish caused by DDD poisoning may yet occur without further treatment of the lake.

SUMMARY

1. A study is being made of the effects on wildlife of DDD used in gnat control programs at Clear Lake, Lake County, California. The study began in May, 1958, and is being continued at the date of this writing.

2. This paper is based on chemical analysis of animal tissue of specimens collected at Clear Lake and on information obtained during field investigations in that area.

3. Conclusive results obtained during the study were:
   (a) All fish, bird, and frog samples analyzed contained DDD.
   (b) The amount of DDD found in all flesh samples exceeded the specified rate of dilution of active insecticide in the lake water on a p.p.m. basis.
   (c) Flesh samples of largemouth bass and Sacramento blackfish hatched between seven and nine months after the last DDD application contained 22 to 25 p.p.m. and 7 to 9 p.p.m. of DDD, respectively.
   (d) All areas of the lake contained DDD contaminated fish.

4. Conclusions based in part on circumstantial evidence were:
   (a) Grebe losses occurring after DDD applications were caused by chronic DDD poisoning.
   (b) The nesting population of grebes at Clear Lake has declined as a result of DDD treatment of the lake.
   (c) Certain species of fish possess a greater tolerance for DDD than do grebes.
   (d) Because of a difference in food habits carnivorous fish accumulated a greater amount of DDD than did plankton eating fish of the same size.

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NOTE

RECOVERY OF TAGGED BLUEFIN TUNA (*Thunnus saliens*)

The wily bluefin tuna is captured almost solely by purse-seines from areas off the coasts of Southern California and Baja California. One area is adjacent to Guadalupe Island, some 140 miles off the Mexican coast.

Early in 1958, one of us, Mr. Orange, was on board the San Pedro purse seiner *Columbia* through the courtesy of the skipper Mr. Frank Gargas. The purpose was to develop techniques of tagging the tropical yellowfin (*Neothunnus macropterus*) and skipjack (*Katsuwonus pelamis*) tunas captured by seine gear from waters near the Revilla Gigedo Islands. Fishermen are opportunistic, however, and upon finding catchable schools of bluefin in the immediate vicinity of Guadalupe Island, the *Columbia* seined there from January 31 through February 19, 1958. One hundred twenty-one bluefin were marked with yellow plastic loop tags, fastened through the back of each fish beneath the second dorsal fin. Eight, or 6.6 percent of these had been recaptured by purse-seines within seven months, but there were no additional recoveries during the next year, up to the time of writing (Table 1 and Figure 1). The tagged bluefin recovered from the cannery on August 16, 1958, was captured during August, by one of seven purse-seiners while fishing near the Los Coronados Islands about 20 miles south from San Diego.

TABLE 1

Release and Recovery Data for Tagged Bluefin Tuna

Release		Recovery		Time free days	Movement (miles)	Length on recovery (inches)
Date	Location	Date	Location			
Feb. 2, 1958	S. end Guadalupe Is.	Feb. 16, 1958	N. end Guadalupe Is.	15	20 N.	
Feb. 7, 1958	N. end Guadalupe Is.	Feb. 10, 1958	N. end Guadalupe Is.	4	Nil	
Feb. 7, 1958	N. end Guadalupe Is.	April 20, 1958	24 miles S.S.E. of San Clemente Is.	73	195 N.	
Feb. 11, 1958	S.W. side Guadalupe Is.	April 22, 1958	20 miles E. of San Clemente Is.	71	230 N.	32.2
Feb. 11, 1958	S.W. side Guadalupe Is.	Aug. 22, 1958	50 miles S. of San Clemente Is.	193	194 N.	34.4
Feb. 19, 1958	Off W. Anchorage, Guadalupe Is.	July 10, 1958	45 miles S.W. of St. Augustine Pt., Cedros Is.	142	150 S.E.	31.7
Feb. 19, 1958	Off W. Anchorage, Guadalupe Is.	July 19, 1958	12 miles W. of St. Augustine Pt., Cedros Is.	151	160 S.E.	32.1
Feb. 19, 1958	Off W. Anchorage, Guadalupe Is.	Aug. 16, 1958	"Found in cannery"	?	?	

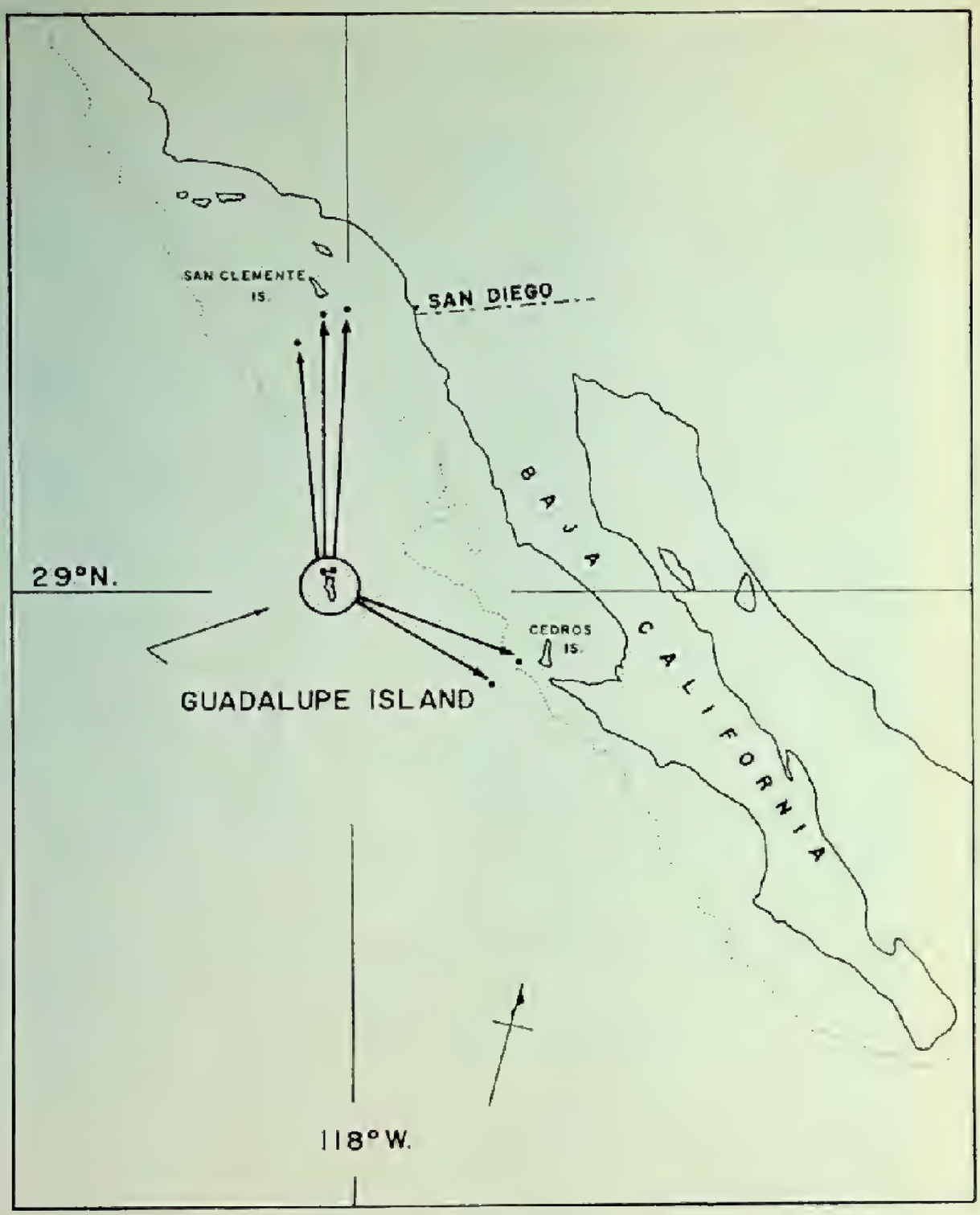

FIGURE 1. Dispersal of tagged bluefin tuna. Each arrow indicates the shortest distance between the release and recovery location.

While the origin of the bluefin tagged and released at Guadalupe Island remains unknown, dispersal of a few tagged fish to the north and to the southeast sheds some light on their movements from there.

Because prolonged handling of tunas during the tagging process could cause the fish to die, length or weight measures were not taken. Hence, the growth rates of the tagged fish recovered are indeterminable. Length measurements of a number of untagged fish taken from

the same seine hauls, however, give some idea of the sizes of the fish tagged. On February 11, 1958, the measured bluefin ranged from about 27 to 33 inches in fork length, and on February 19, 1958, the length range was approximately 27 to 32 inches. The average length of the fish in each sample was a little more than 29 inches. Upon recapture only one tagged bluefin exceeded the maximum length recorded at time of tagging.—*Bruce M. Chatwin and Craig J. Orange, Inter-American Tropical Tuna Commission, Scripps Institution of Oceanography, La Jolla, California, September, 1959.*

REVIEWS

Principles of Fisheries Development

By C. J. Bottemanne, North-Holland Publishing Co., Amsterdam, Netherlands 1959; xvi plus 677 pp., 3 figures. $12.

As Chief of the Institute for the Development of Seafisheries in the Netherlands East Indies and as an adviser to a trawler company in Holland, the author has had considerable practical knowledge concerning the problems of keeping a fishery economically profitable. Although this book is written with the fishery administrator in mind any biologist can get from it a wealth of information and background material on the economics of fisheries. This is not a book that can be read in a couple of evenings. There are many economic terms unfamiliar to the biologist and many fishing terms strange to the economist. Following each chapter is a section of explanatory notes that ranges in size from 2 to 23 pages. The greatest use of this book will be in becoming acquainted with the material and referring to it in the future.

On the first page the author states that the principles governing fisheries should hold good for all kinds and types of fisheries effort aiming at the seizure of any living produce of sea and of fresh water basins and streams. He then defines and explains the worldwide fisheries and methods existing today and breaks these down to the least common denominator "fishing unit" whether it is a hook or a seine. The principle of eumetric fishing and its advisability for the continued utilization of a resource is mentioned, while noting that as long as an entrepeneur makes a profit he does not care whether fishing is eumetric or not.

The history of expansion of existing fisheries is treated next. The author's close association with the European trawl fisheries has made him cognizant of these problems and he devotes considerable space to these fisheries. Many quotes from the published record of these fisheries makes the bibliography extremely valuable.

The role of complementary industries is brought up and it is pointed out that the dollars and cents received by the fishermen must not be the only criterion of the value of a commercial fishery. Consideration must be given to the production of fishing gear, ship building, engine and vessel repair facilities, electronic equipment, ice factories, cold storage, fuel agencies, ship chandlers, and insurance and banking facilities as examples of subsidiary industries that are stimulated by the growth of a fishery. Second in line are the manifold complementary industries which market, process, trade, transport, and retail the landings.

The latter part of the book is devoted to the development of new fisheries or the expansion of existing fisheries in both transitionary and complex countries. In the development of fisheries in the transitionary countries, "the real bottleneck is likely to be not the lack of adequate responsiveness of the masses * * * but the scarcity of teaching and of teachers able to impart it."

Also, it is often desirable, if not necessary, in the development of fisheries to have a fishery research vessel carry out considerable exploratory fishing, an extremely expensive operation. The author advocates the sale of the catch made by the vessel, estimating the cost of operation may be reduced as much as 40 percent. This theory is not generally practiced by the fishery agencies in the United States today.

The review copy was paper bound and was not adequate for a book of this size. It is hoped that the published version will have a more durable binding. A minimum of typographical errors was noted for a book of this size.

This is a book that should be available for reference by fishery administrators and biologists—*E. A. Best, California Department of Fish and Game.*

River Pollution—1: Chemical Analysis

By Dr. Louis Klein; Academic Press, Inc., New York, 1959; ix + 206 pp., $6.

This, Dr. Klein's most recent effort, represents an enlargement of the two chapters concerned with methods of detecting and determining water pollution in his well-received *Aspects of River Pollution*, published in 1957. In spite of its brevity, this

is the most comprehensive work I have found in this field, by merit of the variety of pollutants which are discussed. This is not an analytical "cook book," listing procedures in a step-by-step fashion. Instead, Dr. Klein discusses the reliability of the determinations—the pertinent theory, interfering substances, and significance of the results. In most cases he outlines the most advantageous reagents and equipment, and makes an earnest attempt to distinguish between those methods which may be undertaken in the field and those which must be confined to the laboratory.

The author does not attempt to recommend water quality criteria. This he has attended to in *Aspects of River Pollution*. His concern is to present the most valuable and up-to-date information on such important aspects of water quality as dissolved oxygen and oxygen demand tests, nitrogen compounds, sulfur compounds, pH relationships, carbon dioxide, the halogens, and metallic contaminants.

Perhaps the most outstanding feature of this book is the bibliography of nearly 600 references, of which no less than 87 cover work published within the last two years. Many of these references are to publications in the biological sciences which deal with requirements of specific organisms or groups of organisms. This bibliography, together with the wealth of background information presented in the text, should make this book invaluable to the sanitary engineer, pollution bioanalyst, or aquatic biologist—*William M. Kier, Inland Fisheries Branch, California Department of Fish and Game.*

Dangerous Marine Animals, That Bite—Sting—Are Nonedible

By Bruce W. Halstead; Cornell Maritime Press, Cambridge, Maryland, 1959; xv + 146 pp.; 89 black and white figures, color frontis. $4.

Dr. Halstead generally has done a commendable job of putting into this small volume a wealth of information on dangerous marine animals. None of the several categories has been exhaustively covered, however. As in compiling any tome such as this, there necessitated considerable dependency upon the printed works of others; but wherever possible the author has chosen as representative species those with which he was thoroughly familiar.

Although a few of the entries appear subject to challenge, it is my belief the author did the right thing to include these. It is better to be safe than sorry where human lives are concerned. Regardless, one cannot help but wonder as to the number of truly dangerous beasts remaining unreported and unrecognized while various implicated "killers" are being unjustly persecuted.

To have been really complete, Dr. Halstead should have inserted a short section on the various marine animals that shock. They are certainly a minority group, but in these days of ever-increasing skindiving and spearfishing activities contact with a large electric ray could be an illuminating experience to an unenlightened individual.

After the usual introductory material, the author takes the reader through a short historical account of our knowledge of dangerous marine animals. This is followed by separate sections on animals that bite, that sting and that are poisonous to eat. For many of the species there are notes on recognition characters, geographical distribution, habits, habitats, and so on. Preventive measures are suggested to keep one from becoming involved; however, if these do not work there are discussions on the medical aspects and treatment of the resulting wound, symptom or illness.

The volume is profusely illustrated, although four of the figures (2A, 3A, 52 and 53) need to be repositioned in the text.

The testimonial on the dustjacket, that it is "a handbook for skindivers, swimmers, physicians, first-aid workers, shell collectors, biologists, explorers, and everyone who works or plays in or on the seven seas" seems to be reasonable as does the asking price for the book.—*John E. Fitch, California Department of Fish and Game.*

Shark Attack

By V. M. Coppleson; Angus and Robertson Ltd., Sydney, 1958; xvi + 266 pp., illus., 32s.6d.

For over 20 years Dr. Coppleson, a Sydney surgeon, has been studying the medical aspects of shark bites. In this book he has gathered information on all the shark incidents reported in Australia since 1919. He has also included accounts of as many shark attacks from all over the world as he could find.

By tabulating time, water temperature, and latitude he was able to establish a timetable of shark attacks for Australian waters. Most occurred between 2 p.m.

and 6 p.m. in areas where the water temperature was approaching or above 70 degrees F. It was possible to construct a similar timetable for attacks reported on the East Coast of the United States. However, on the West Coast of the United States no definite pattern could be established.

The theory of a "rogue shark," one that having tasted human flesh will look for further victims, is fully developed. Means of protecting beaches that have become unsafe for swimming due to the presence of sharks are discussed. Protective measures are given for an individual menaced by a shark. There is no disputing the terror that can be created by a shark at a swimming beach; however, the odds of an attack are infinitesimal.

This book contains much valuable information for those whose work or play brings them into contact with warm ocean waters.—*E. A. Best, California Department of Fish and Game.*

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printed in CALIFORNIA STATE PRINTING OFFICE

6694 10-59 5,200

DEPT. OF BIOCHEMISTRY
UNIV. OF CALIFORNIA
DAVIS, CALIF.

JAN 14 1926